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Proceedings of the Royal Society of Queensland.

Presidential Address.

BY PROFESSOR E J GODDARD, B A , D Sc

(Delivered before the Royal Society of Queensland, 19th March, 1928)

It is my pleasing duty, as President of the Royal Society of Queensland, to record a year of sound scientific activities on the part of the Society. The general nature of those activities is set out in the Annual Report of the Council which has been read to you this evening.

Before referring to general matters which have the interest of the Society, I wish, on behalf of the Royal Society of Queensland, to express appreciation of the association with the Society of such men as the late Professor Liversidge and the late Professor Rennie, both of whom were corresponding members of the Society, and of the services rendered during a long period of years by the late Dr W F Taylor, who acted as a Trustee of the Society. We regret very much the deaths of these gentlemen, and in realising the value of the help which they gave through their association to the Society at a period when science and scientific effort, such as manifested by the Royal Society, was of less value in the eyes of the community than it is at the present time, we offer to their relatives and friends our sincerest sympathy.

There are several matters which, as retiring President, I consider should be mentioned on such an occasion as this in the interests of the Society. The Royal Society of Queensland is dependent for its existence on a membership roll which is far too limited in numbers, and on financial support from the Government of Queensland, which assistance we gratefully acknowledge. As President of the Society, I do feel that there are many members of the community whose professional interests and general outlook on life are scientific or incline in that direction, and who might be expected to throw in their lot with the Society. It is frequently stated that the subjects which constitute the basis of discussions at our ordinary meetings, and which form the substance of our Annual Proceedings, are limited and specialised to an extent that defies interest to many of the class to whom I have alluded. I would like to say, as President of the Society, that this is no fault of the Society itself. Any restriction on the nature of subjects coming before the

Royal Society arises from the restricted interests of the members constituting the Society. The Council would welcome a greater variety of scientific contributions, and would be pleased to welcome to the membership of the Society all those who take a real interest in matters scientific.

There is one other matter in connection with the activities of the Society that calls for specific mention, and that is that the Royal Society not only places no limit on the nature of the scientific contributions placed before it, but is anxious to foster all forms of economic or applied research.

The Council notes with satisfaction the increased and intensified interest being manifested by Commonwealth and State Governments in matters scientific, and while this interest is largely in the direction of scientific research in relation to industry and production, yet it indicates practical sympathy with scientific effort. It is noted with pleasure that the Council for Scientific and Industrial Research is appointing a staff of first-class scientific men to deal with problems of importance to industry and production in all its branches, and in so doing is setting an example by offering emoluments sufficient not only to attract first-class men but to encourage younger men to appreciate that there are better opportunities ahead than has been the case in the past. The Council notes with pleasure the appointment of a Board of Agriculture by the Government of Queensland, and representative of the various bodies concerned in agricultural research within the State, with a view to co-ordinating the activities of these various State bodies *inter se* as well as with the activities of the Council for Scientific and Industrial Research and the Development and Migration Committee. The Royal Society of Queensland, as the oldest scientific body in this State, can view with satisfaction these happenings and developments, for the Royal Society of Queensland has, from its beginning, encouraged interest in scientific research for the sake of science, realising long before any appreciation of science was engendered in the minds of the community, that scientific research lay at the basis of human development.

The Society welcomes the activated interests of Governments in scientific research, and while recognising that there is still a long way to go before industry in general appreciates to the full the dependence of its future efficient development on science, yet faces the future in this respect with optimism. It is hoped that in this march towards advancement younger members of the present and future generations possessing a love or aptitude for science will be attracted to the fields of scientific research. This is one of the great needs in Australia at the present day.

* * * * *

VIRUS DISEASES AND THEIR BEARING ON THE CELL THEORY AND OTHER BIOLOGICAL CONCEPTS

I have chosen as the title of my Presidential Address this evening that of "Virus Diseases and their bearing on the Cell Theory and other biological concepts." I do not propose to attempt anything of a

monographic nature on virus diseases—such would be premature—but to indicate to you the importance of these diseases and their relation to humanity from an economic and scientific standpoint. Any investigator concerned with researches into virus diseases is constantly being drawn in mind towards many somewhat abstruse and very imperfectly understood fundamental biological problems. Although I do not claim any specific originality in respect of the general subject matter of this address, yet I would say that association with certain investigations into a plant virus disease has for the past few years largely dominated my mental horizon in so far as biology is concerned. I feel that a Presidential Address offers a special opportunity—which should be seized—of presenting some subject which has wider scientific incidence, more constructive value, and greater general interest than a specialised scientific paper which might be expected to find its place in the Proceedings of the Society. To my mind no biological problems have more fundamental scientific significance immediately than those of virus diseases, nor is there any biological problem confronting us to day which appears to have greater significance in so far as humanity is concerned. We know comparatively little about the problem of living matter, we have been nurtured with certain ideas that dominate our biological horizon, such as the cell theory, which occupies in the mind of the biologist the position that the atom occupied in the mind of the chemist until comparatively recent years. The atom still constitutes a necessary unit in our mental catalogue for descriptive chemical purposes, but a desire for a more profound understanding of the inorganic world, and the attainment of that philosophic perspective which is synonymous with the term “scientific,” compels us to have regard for such ideas as the identity or equation between energy and matter and the quantum theory. In the same way the cell will always remain as a useful working unit in our mental catalogue for descriptive biological purposes, but the tendency to regard such a unit as the ultimate entity in considering problems within the realms of biology must be avoided. The cell theory will remain, but biological ideas will progress.

Virus diseases have a variety of interest. Firstly, their significance from an economic standpoint is being forced on us with increasing stress each succeeding year, and it seems highly probable that gradually the most important of our domesticated plants will yield examples of these insidious maladies. They have their incidence also in the animal kingdom, where numerous diseases have been proved to be due to the presence of an ultra-virus. In so far as plants are concerned, it would not be stigmatised as a gross exaggeration of the present position to prophesy that virus diseases directly and indirectly will ultimately dominate the science of plant pathology. Such a statement need not necessarily be construed as suggesting that something of a catastrophic character has been delivered by Nature, it simply means that with increased knowledge, not only of natural living objects themselves, and arising out of that, the availability of more subtly devised means and technique, we are enabled in our attempt to diagnose the mysterious

ills of plants to get down nearer and nearer to the basic idea concerning the problems of living matter. The ultimate goal will never be reached; we are simply passing milestone after milestone, reaching nearer and nearer to that unattainable goal. New problems will arise as we progress; what once merited the status of a cause will be relegated to that of effect, what appears to be a basic idea of to-day becomes merely a further acquisition of knowledge to-morrow. Further, it may well be that, in plant-virus diseases at least, we are viewing the results of a disturbance in the balance of Nature in a way which will be indicated later in this address; or it may be that we are paying the price for an intensive effort in the direction of plant domestication. Such ideas have arisen in the past, and still continue to arise in the minds of investigators confronted with the problem of virus diseases. The whole matter of plant-virus diseases was considered recently at the Imperial Agricultural Conference, and it was there decided that one of the most important avenues of research meriting attention throughout the British Empire was that of fundamental research into virus diseases.

This may serve to indicate that I have not exaggerated the importance of my subject from an economic standpoint.

Secondly, virus diseases would, according to our present interpretation of their nature and cause, seem to open up a sphere of investigation of intense scientific interest, inasmuch as they lead us directly in our present state of knowledge to an intensive attempt to unravel the mechanism and physiology of the cell.

Thirdly, bound up with what I have mentioned above, is the high possibility that investigations into virus diseases may lend very important help to an understanding of the nature and cause of cancer, as well as unravelling the reasons which lie behind the beneficial effects which are derived in certain cases at the present time by various types of irradiation.

The idea that there were beings of such minute size as to be invisible under the highest powers of the microscope received mention as early as 1674, i.e., over two centuries ago. Even Pasteur, who did so much to throttle the idea of spontaneous generation and secured a firmer and firmer basis in biology for the cell theory by his bacteriological studies, once stated that if the causal organism of rabies could not be seen under the microscope, then it was simply because its dimensions were too small for the limits of visibility of this instrument. As I propose to devote attention this evening, in so far as virus diseases are concerned, to examples drawn from the plant kingdom, I may be permitted to give a brief résumé of the history of plant-virus diseases.

The earliest discovery of a plant-virus disease was made in 1893 by Iwanowski, who showed that a mosaic disease of tobacco was a contagious disease, and that the causal agent could be passed through a filter candle. Later experiments within the next two years corroborated the extreme minuteness of the contagious element, and led to the development of the

hypothesis that the contagious element was a *contagium fluidum vivum*. Since that time many other filterable viruses have been discovered, although it has been proved that some of these are no longer to be regarded as true viruses, i. e., ultra viruses, but represent minute organisms, such as bacteria, etc. Virus diseases are now known to be represented among the diseases affecting such a wide range of plants as tomato, turnip, potato, sweet pea, asters, beans, bananas, beet, cabbage, celery, cucumber, sugar-cane, hop, lettuce, melon, pea, peanut, raspberry, pepper, cineraria, clover, cotton, corn, spinach, soy bean, tobacco, etc. The list is not to be regarded as complete. For a very long time many of these diseases were placed in the category of physiological diseases, but gradually as suspicion of the presence of an ultra-virus was aroused a development of our knowledge of the symptoms led to a systematising of those symptoms which now places us in a position to at once suspect the virus nature of the causal agent in such diseases. One feature common to all virus diseases is their transmissibility from diseased to healthy plants, due to the presence of something which we term a virus or ultra virus,—perhaps the latter term might be used.

There is one significant feature about virus diseases, and that is the symptoms of the disease in a particular plant may include certain appearances, malformations, etc., which occur in otherwise healthy plants as the result of environmental influence, some due to one particular environmental factor, others to another and so on. With respect to transmissibility, virus diseases fall into three groups, namely, those in which the disease can be transmitted by inoculation of the juice from a diseased plant into a healthy plant, by grafting or through an insect vector; those in which insects and grafting serve to transmit the disease, and those in which the disease is transmitted by budding or grafting, no insect vector having yet been discovered, and inoculation experiments having failed.

In general, those types of virus disease in which transmission can be effected by inoculation are termed mosaic diseases, but, not only is there no reason for regarding causal agents as falling in a different category to that in which is included the causal agent of other plant-virus diseases, but there are so many points of resemblance between the two groups that, in the present state of our knowledge, we should not stress the importance of our inability to effect the transmission by artificial inoculation. Both groups are systemic diseases, that is to say, all parts of the plant are affected, and further, there is no hope of recovery on the part of the plant when the disease has once appeared. In the case of mosaic diseases the symptoms are fairly uniform, but in the case of non-mosaic types there is a wider variety of symptoms, although, as in the former, the foliage is markedly affected and there is a conspicuous dwarfing of the shoots. In Australia several outstanding examples of virus diseases have called for investigation, and it is pleasing to record that in some cases investigation has resulted in a determination of the nature and mode of transmission of the disease. I refer to tomato wilt

and bunchy-top in bananas. The former has been proved to be a virus disease of the non-mosaic type which is transmitted from plant to plant by the insect *Thrips tabaci*, the second is also a non-mosaic virus disease which is transmitted from plant to plant by the banana aphid, *Pentalonia nigronervosa*.

In the investigation of the latter disease, a very thorough pathological examination which was continued throughout the period of investigation failed to reveal any bacterial or fungal organism which could be regarded in any way as contributing to the cause of the disease, although various investigators previously considered the possibility that some fungus would be associated with the disease. The experiments which proved, or were regarded as proving, the virus nature of this disease, have been repeated many times since, not only here but elsewhere, and it is satisfactory to record that the theory of the virus nature has in every case been substantiated. The association of an insect vector in both these cases was rendered difficult of detection at first in the field, and to some extent this is linked up with the fact that a considerable period elapses after the transfer of infected insects to healthy plants before the symptoms of the disease appear, sixteen to twenty days being required in the case of tomato wilt, twenty six in the latter case. No doubt this period is spent in the propagation of the virus within the plant, for it must be said that one cannot get away from the idea that the symptoms and development of a virus disease insistentlly proclaim that the virus substance is capable of propagation. Rather does this appear to be the case than that any developmental phases are passed through within the insect, comparable to the phases of the life-history specifically restricted to the period within the insect in the case of protozoan diseases, such as malaria. While sufficient has been discovered in the case of bunchy-top to enable the framing of recommendations which are proving effective in the direction of controlling and eradicating the disease, there still remains a great deal to be done on the scientific side, especially in view of the fact that the banana plant offers excellent material for the investigation of a virus trouble. Researches are still being conducted, and these embrace such studies as the determination of the life history of the aphid, the number of generations of aphides through which the virus may persist, the determination of other possible host plants of the aphid, the examination of such plants, other possible vectors of the disease, and the possible relation of other host plants to the infection of the banana, determination of the possible locus or loci of infection in the banana by aphides with special relation to the meristematic tissues. The last mentioned inquiry is one of extreme interest inasmuch as the phloem of the banana plant is affected by the virus in such a way as to suggest the possibility of throwing light on such problems of disturbed metabolism, growth and reproduction of cells, as occurs in cancerous tissue. Further, the disease, in so far as the tissues of the plant are concerned, is not retrospective, that is to say, non-meristematic tissue developed before the introduction of the virus, is not visibly affected from a structural point of view, and this leads

in the direction of offering opportunities for work on readily accessible material which may throw light on the persistence of the meristematic or embryonic function of cancerous tissue

Another very suggestive line of inquiry is that of a study of means of preventing the development of the disease when loci of infection are discovered. This opens up an opportunity of testing out the effect of different types of irradiation in a very convenient way. Irradiation in relation to meristematic tissues and cancer problems opens up an alluring field of investigation. It is of interest to record in this connection that the only record that we have of anything approaching the status of observed evidence in support of the now commonly accepted belief that the so called ultra-viruses are particulate, comes from ultra microscopic investigations associated with cancer investigation. I hasten to add, however, that the evidence cannot yet be regarded as overwhelmingly convincing. Then arises the advisability of carrying out investigations bearing on the latency of a virus disease for which again the banana plant offers excellent material. There is more than a suspicion at the present day that banana plants may act as carriers of bunchy top, that is to say, they remain as apparently healthy plants, serving to distribute the disease either through descendent portions of the plant or through the insect vector. Then there is the important point of the transmission of the disease to other plants of other species, which may throw very important light, not only on the nature of the virus, but more particularly on the origin of the virus or virus particle in the first place.

The inability to detect any visible causal agent was responsible, as we have heard, for the idea that some new type of agent was responsible for the disease, and so arose the idea of a *contagium vivum fluidum*. Opposed to this have been developed other theories which embrace bacterial origin, enzyme origin, protozoan origin, etc., of the causal agent. There are to day at work in every civilised country investigators concerned with virus diseases, and there is a general consensus of opinion among these workers as a result of intensive study of the development of the symptoms of various virus diseases that not only are we concerned with what we term a virus, but that that virus is also particulate. This interpretation is consistent with the occurrence of filter passing bacteria and the reasonable suggestion that still smaller bacterial (?) forms might be expected to exist—all this leading to a continuity of serial forms the ultimate members of which would be inadmissible as cellular forms. By means of special filters comparative measurements of the size of these supposed particles have been made, although it can hardly be accepted that the precautions adopted and the results attained are by any means beyond reproach. Further work along these lines will have, in my opinion, a very important bearing on the scientific problems of the cell. With the aid of the ultra-microscope and the assistance of bio-physics possibilities are offered, after establishing beyond doubt the existence of a particulate virus, for determining the relation of, say, protein molecule or molecular aggregate to micella and to the ultimate particle which patently carries all the attributes of living matter.

Less than a century ago the enunciation of the cell theory opened up a new line of attack on biological problems, and this idea began quickly to dominate biological thought. Thus it came about that the cell theory was accepted as fundamental to biology as the atomic theory to chemistry, and the present status of biological science rests on the advancements made by the adoption of this cell theory which offered to the world the idea of a unit or entity which marked the starting point of the animal or plant individual, and dominated the make-up of the fully grown animal. From a historical standpoint it is of interest to record the activities of a group of naturalists who, at the period referred to, were developing a knowledge of the facts demonstrating the idea of organic evolution. Their investigations proceeded along independent lines, taking no cognisance of the newly discovered basic unit. This was actually the position when the idea of organic evolution had taken concrete shape in the hands of Darwin. During the last quarter of the nineteenth century the clearer conception gained of the cell led to a great advance of our knowledge of this unit of the animal and plant bodies, and such studies began to link together the problems of structure, development, growth, heredity, and evolution. The beginning of the twentieth century initiated a series of illuminating advances which have served to encourage biological knowledge of a more exact and quantitative order, and are yearly bringing us to a more profound and fundamental outlook on the problems of living substance. By a strange coincidence the rediscovery of Mendel's Laws of Heredity was made in the year 1900 by three independent workers, and the theoretical interpretation of the phenomena dovetailed in a most complete and satisfying way into the development of knowledge on the cytological side. Since that year our knowledge of the cell has forged ahead, and all this has served to substantiate more and more strongly the aphorism *omnis cellula e cellula*. The idea that the cell represents the ultimate unit of life or living material has thus become more and more the working idea of the biologist,—at least, in so far as the individual organism is concerned. The complexity of the cell with its organisation slightly more comprehensible to us to-day lends very little weight to any idea of the possibility of cells arising *de novo* or by any form of spontaneous generation. Our knowledge of bacteria has added weight to this attitude and helped very materially to effect a sort of stabilised position in so far as the cell theory is concerned. Even when danger threatens by the inability to determine under the microscope a specific organism, its ultra-microscopic nature and filterable size was accepted, and yet the cellular entity of the organism maintained.

For a very long time—in fact the old idea still persists in the minds of many—it was believed that protoplasm possessed a definite physical structure, and such structure was regarded as a necessary feature of protoplasm, enabling it to discharge its vital functions. The heterogeneity of the particles commonly found in the cytoplasm led to the elaboration of various theories of visible structure, such as the reticular, alveolar, granular, etc., theories. The position at the present day is that there is no acceptable theory of visible structure, and the appearance of oft-

claimed structure are regarded either as temporary phases in the individual cell or as artifacts. The development of reticular and alveolar structure as the result of experiments in the coagulation of solutions of albumens, etc., has been demonstrated. The adoption of this idea is not tantamount to denying an organisation in protoplasm, but any fundamental structure is certainly of an ultra-microscopic order. Recent work along the line of micro-dissection of cells demonstrates very definitely the absence of any plan or organisation of a grosser or visible order. The activities of protoplasm are carried through in a visibly homogeneous mass that subscribes to the condition of a colloid, such a nature being demonstrated by its behaviour and not structure. When structures do appear at times within the protoplasm of the cell the decision as to whether they are to be regarded as living or non-living structures exercises no prejudicial influence on the conception that protoplasm has an ultra-microscopic fundamental make up.

While the idea of a grossly homogeneous protoplasm represents a modern point of view, the suggestion that it possesses an ultra-microscopic pattern is by no means new. Hosts of investigators have suggested such a metastructure, and have offered definite names and functions for the particles which were regarded as of the order of aggregates of molecule or micellæ, capable of growth and division. I need refer only to a few of these, such as the physiological units of Spenser, Darwin's gemmules, de Vries' pangens, Nageli's micellæ, Altmann's bio-plasts, Weisman's bio-phors. Such ideas of ultra microscopic units have met with much opposition from cytologists, who regarded cell structure as the last word in the structure of protoplasm. The modern view of geneticists that there exist in the nucleus particles of specific make up responsible for definite characteristics of the individual organism must stand for the present, in view of the success in interpreting genetic problems that result from the adoption of the idea. What obtains in the nucleus might reasonably occur in the cytoplasm. If we are prepared to retire from a prejudiced position which would regard the cell as not merely a colloidal system but as the ultimate entity in so far as life is concerned, and to examine the matter from the standpoint of evolution, the existence of virus particles possessing the power of growth and reproduction would appear to offer ground for adopting a broader and more constructive view of the cell.

If living substance was derived originally from non living material, that is to say, there has been a transformation of inorganic to organic, then surely there must have been stages in that evolutionary scheme when something much more primitive and less highly organised than the cell represented the living material, and to that something we must give a particulate nature. While admittedly there are shown, among living cellular organisms, varied conditions of differentiation with respect to cytoplasm and nucleoplasm, yet even in the simplest of these there is a complexity of structure and organisation which defies us in any attempt to regard them as approaching in simplicity the earliest forms of life.

There are, within the cytoplasm and nucleoplasm of cells, bodies which maintain their identity and autonomy and possess the power of reproducing themselves. I refer to structures which are actually visible under the microscope, such as plastids, but on top of this again, we impress the idea of certain hypothetical, ultra microscopic particles which likewise possess the power of self-propagation and independence, such as the genes whose existence, based on the result of accurate genetic studies, can be assumed with as much assurance as that of atoms and molecules. The term "living" may have absolute or relative significance for different minds, but adopting the qualities by which we are accustomed to distinguish living from non-living material, we must bestow the term "living" on such visible masses as plastids, and such hypothetical bodies of a smaller order as genes. We may readily attribute to such particles as genes, which, in the present state of our knowledge we regard as the agents responsible for the carrying of specific qualities to the individual, that is, to the cell, an individuality of an intrinsic order—something, may I be permitted to say, corresponding to what we have learned to speak of within recent years as the psychical element of psychism.

It is no doubt desirable in a scientific paper to restrict oneself to the detailing of facts, reasonings, and observations, and to refrain from any ultra imaginative effort to construe the meaning of such except along such lines as might be regarded, from the scientist's standpoint, as fully justified by the facts. In a Presidential Address, however, one may, perhaps claim a little license and depart so far from the purely scientific arena as to venture on to ground which is the prerogative of the metaphysicist. Chemistry and Physics have been fundamental to a comparative understanding of biological problems, but it may be said with as much truth that biology has much to offer those sciences for an understanding of Nature. The ultra materialistic attitude which would, in uncontrolled language, express itself by alleging that the problem of life is interpretable in terms of the laws of chemistry and physics, fails to recognise that the dominion of physics, for example, has been so widened as to now vaguely include the very problems which lie intrinsically at the basis of life, and that a wider interpretation of biological science may render clearer to the physicist many of these fundamental problems. The developing knowledge of to-day suggests that biological science requires, for the elucidation of its problems, more than the application of known physical and chemical laws. The living cell is a psychic unit. Whether that psychism is restricted to the organic world we do not know—so far, needless to say, it has not called for specific consideration by the chemist or physicist. No doubt when we know more of the ether and of the fundamental relation of space, time, and thought, an appreciation of psychism will be dominant in the mind of the future bio-physicist and bio-chemist. Is the ether particulate? Is there a unit of psychism? What is the relation of such a psychon to the ether, etherion, electron, atom, molecule, gene? Such are problems which are suggested in any attempt to interpret aright the make up and genesis of the cell.

The development of the idea that the cell was a biological unit was accompanied by what is regarded as definite disbelief of the possibilities of spontaneous generation. The idea that an organised cell could arise in any way other than as a descendent of a pre-existing cell would to-day be regarded as preposterous, and rightly so, in view especially of what we know of the complexity of cell architecture. All this points in the direction of suggesting that the organised cell arose at some definite period in the history of the earth, and that the necessary conditions then existing no longer obtain. The exact nature of those conditions we do not know, although many theories are advanced. Foremost among such theories, and probably meriting major support, although relegated to the status of speculation, are such as attempt to associate the origin of living matter with the special phase of solar irradiation, accompanied by special conditions obtaining on our planet at that time. Developments in physics during recent years would seem to lend some weight to this idea, as also do the results attained chemically by the utilisation of ultra-violet rays in certain otherwise impossible chemical syntheses. On the whole it would appear that the other sciences uphold the biological argument with respect to spontaneous generation in so far as the cell is concerned.

I do not feel it incumbent on me to meticulously follow through the stages in the evolution of the cell. Such would be an impossible task—a mere speculation without even any supporting gesture of fact.

The general theme which I have so far outlined to you suggests that the protoplasm of the cell is particulate, that these particles possess the attributes of life, and that such probably represented a stage of living matter antecedent to the organised cell. How and why that organisation was affected I would not attempt to postulate, nor would one care to pronounce definitely that the particles which are postulated as the component units of protoplasm cannot arise *de novo* at the present time, although the acceptance of such a possibility would be very difficult. I may, however, refer to the fact that in the investigation of virus diseases the possibility of a development of the disease *de novo* is rightly kept in view. So far there has been no record of any observations carrying the weight of evidence behind them in support of such an idea, which quite possibly might be used as an argument, but certainly not convincing, in favour of the particulate nature of the virus.

Such ultra-microscopic particles entering into the make up of protoplasm might be regarded as endowed with specific qualities—possibly endowed with psychism—and the characteristic qualities of the cell would be determined by the inter-reaction of the various particles in much the same way as it is considered by geneticists that the genes in the chromatin of the nucleus exert their influence. What the nature of these bodies from a physical or chemical standpoint would be we do not know, but our ignorance in that respect could be attributed to the same cause as our ignorance of many things, physical and chemical, of a fundamental order.

The latter part of this address may appear to be far removed from the subject of virus diseases, but I have attempted to indicate that the study of virus diseases has a truly scientific interest far beyond that of a mere economic order. Some observations made by an American worker less than three years ago bring out the connection between the earlier and later parts of this address in a very suggestive way. This worker claimed to have produced a mosaic disease in tobacco by inoculation of the tobacco plant with extracts from what appeared to be normal and healthy potato plants. If such observations are proved to be correct, and if the particulate nature of the virus were substantiated, then it might be suggested with much reason that the origin of virus diseases might lie in the transportation of minute living particles from one species of a plant to another. In the experiment mentioned, the two species are comparatively closely allied, and, adopting the idea of genetic relationship, we might regard the particle from the potato substance as being sufficiently closely allied to the particles entering into the make up of the cells of the tobacco plant as to ensure their fitting in with the scheme of organisations which constitute tobacco cell life, but at the same time sufficiently foreign or riotous as to engender a pathological condition. The experiments just outlined have not been substantiated, but at least they suggest a sane possibility for the origin of virus diseases, and furthermore, indicate that possibly insects which, as we have seen, play an important part in transmitting various virus diseases, may have been responsible for the origin of these diseases. We have a parallel in the case of many protozoan parasites where we find forms restricted to the alimentary canal of insects, and other closely allied forms which spend part of their time in the alimentary canal of insects, and other phases of their existence as parasites in the blood system of other animals, the insect serving as the vector. Aphides in particular play a very important part as vectors of virus diseases, and, it is noteworthy, the meristematic tissues at the growing point are particularly attractive to aphides. Further, aphides in general have a complicated life history, and during that life-history they become variously adapted in many cases to different host plants. All this is very suggestive.

The field of virus disease is thus a very attractive one, and must ultimately enlist the interest of the future bio-chemist, and notably of the future bio-physicist. The study of these diseases combines in an excellent way attractions for the pure biologist and the economic biologist

Investigation into Sewage Disposal in the Brisbane Estuary.

By J V DUNN, M B, Director, Brisbane and District Laboratory
of Pathology

(Three Text-figures)

(Read before the Royal Society of Queensland, 30th April, 1928)

At the request of the old Metropolitan Water Supply and Sewerage Board, I made an investigation into the Board's method of disposal of sewage into the estuary of the Brisbane River. It had been suggested that this method was or was likely to be a nuisance and/or a danger to the public health.

In this work I collaborated with Mr Thom, Sewerage Engineer to the Board (who has supplied me with all the engineering data) and with Mr Chamberlain, the Board's chemist, who not only assisted in the actual work in the field but also supplied check results of the chemical tests used in examining water samples taken.

The results given are those of bacteriological and chemical examinations of samples of water taken in conditions set out in the tables.

In an investigation of this kind, the only result possible is to show whether a sewage disposal system of a given kind is or is not suitable for a given place. The conditions in which this system functions are so numerous and vary so much individually from hour to hour that, in the present state of knowledge, I should hesitate to advise sewerage engineers to draw any but tentative conclusions from my findings. It is almost certain that in no other city in the world do conditions exist exactly analogous to those of the Brisbane system. All that it is desired to establish in this paper is —

- 1 Whether the Brisbane method of sewage disposal is suitable for Brisbane in the sense that it can most economically dispose of sewage without subjecting the population to the risk of æsthetic annoyance and/or danger, and
- 2 That my methods are sound and universally applicable.

The conditions in which sewage disposal is conducted into the Brisbane estuary are as follow —

- 1 Volume of sewage discharged
- 2 Volume of diluent available
- 3 Rate of flow of diluent
- 4 State of the tide
- 5 Direction of the wind
- 6 Oxygen content of the diluent, depending on (a) salinity of the diluent, (b) temperature of the diluent, (c) barometric pressure, (d) depth of diluent.

The value of any method of sewage disposal depends on rapid oxidation of organic material and this in turn is a function of (a) the dilution available, (b) the oxygen content of the diluent

All the above factors are taken into account in this investigation, although very early in its course it became evident that they could be disregarded as rigidly serious components of the problem under investigation. As will later be shown, for instance, wide variation in these factors would have had little influence on the safety of the particular system investigated

I set out my findings under four heads —

- (A) Engineering data
- (B) Facts deduced from these data and from their operation
- (C) Facts obtained by experiment
- (D) Comparison with common standards

(A) The main sewer from North Quay to Luggage Point is eleven miles long. The main sewer (diagram exhibited) varies in diameter from 2 ft 6 in at North Quay to 5 ft at Luggage Point, and can carry 29,000,000 gallons of sewage per day. At Pinkenba the sewage is raised 50 ft, and at Luggage Point 30 ft, and at both these points is incidentally aerated. The volume of sewage discharged at Luggage Point outfall is now 4×10^6 gallons per day. This is equivalent to a depth of between 1 ft and 1 ft 6 in in the 5-ft sewer. The total volume of water passing Luggage Point in the Brisbane estuary is equal to about 200×10^6 gallons at any given moment at mean spring range.

The O_2 saturation of sea water containing 15×10^3 chlorides varies with the temperature as follows — At $15^\circ C$ 8.63 parts per 10^6 to 7.15 parts per 10^6 at $25^\circ C$, sea water containing 20×10^3 parts chloride is saturated when it holds 8.14 parts of O_2 per 10^6 at $15^\circ C$ to 6.74 at $25^\circ C$ [1]

In my earlier tables I have shown the O_2 as parts per 10^6 . In the later tables O_2 is shown only as percentage saturation, the amount per unit volume being easily available by calculation from the tables referred to in [1].

(B) From these data I have made the following general observations. The sewage from the city and suburbs of Brisbane is brought to Luggage Point through some miles of piping. On the way it is exposed in a relatively wide stream to the action of the atmosphere. It is pumped into sedimentation tanks provided with baffles to retain sludge. Here it remains many days.

Inspection of these tanks shows that only relatively less destructible matter, such as orange peel, insects, matches, fish-bones, &c., is not destroyed. The human waste is almost completely reduced to sludge by the time it leaves these tanks. From there it flows at a fast rate into the outfall sewer, and observation will show that in falling the 8 ft or so against the sewer wall, efficient oxidation takes place so

that by the time the sewage reaches the outfall the solid material is reduced to a sludge so finely divided that it takes some hours to settle even in so small a quantity as 1,000 cc of fluid (*This fact was demonstrated before the Society.*) The risk of creating a nuisance is so small that it can be disregarded

Colonel Longley raised certain objections to the Luggage Point site and works to deal with all the sewage on economic grounds alone. He advocated preliminary treatment of sewage in various suburban areas before final discharge at a point higher up the river than Luggage Point. The distance of travel must, however, be a matter of opinion. The establishment of subsidiary treatment works in settled areas would involve bitter opposition and very great expense as compared with Luggage Point which has, to my mind, certain outstanding advantages: (1) The relatively longer pipe line results, as I have shown, in oxidation which is so considerable as to be almost complete, (2) the Luggage Point area is not likely to be settled for a long time, if at all, (3) discharge into the estuary provides an ideal, because cheap and safe, method as against costly and possibly offensive suburban systems.

(C) I made seven examinations of Luggage Point effluent as it reached the estuary

I 16-11-27

Wind N E moderate

Tide --

Flood at beginning of experiment

Slack at end of experiment

Temperature of water 26° C

Sewage flowing for three hours

The effluent formed a sharply marked zone about 30 yds wide immediately opposite the outfall. The sharpness of the line is indicated in the plate counts shown in Table I

TABLE I

Origin of Sample	Plate Count per c.c.	O ₂ in Solution	Chlorine content	O ₂ Satur- ation %
		Parts per 10 ⁶	Parts per 10 ⁶	
1 Centre of "zone" ■	Uncount- able	3.3	15 x 10 ³	50
2 Edge of zone ■	Uncount- able	3.1	20 x 10 ³	73
3 100 yds east ■ {	2	4.02	20 x 10 ³	62
4 50 yds south	1,600	5.15	20 x 10 ³	70
5 100 yds south	4,250	5.25	20 x 10 ³	80
6 200 yds south ■ {	640	5.30	20 x 10 ³	80
7 400 yds south	344	4.95	20 x 10 ³	76
8 500 yds south ■	80	6.4	20 x 10 ³	99
9 10 yds inside zone (north)	Uncount- able	4.75	20 x 10 ³	73
10 30 yds north of zone	45		20 x 10 ³	
11 100 yds north of zone	15	5.23	20 x 10 ³	80

The area examined was shaped as shown in Map 2 (Text-figure 1).

Samples taken are shown thus in map —1, 2, &c.

The plate count of Sample 3 shows the sudden drop in pollution just outside the "zone," and shows how restricted is the polluted area. As the effluent is dispersed by the tide the pollution is reduced to vanishing point.

O₂ Saturation (on which disinfection depends)—The high saturation in Sample 1 is quite evidently due to the relatively low Cl content due to admixture with fresh water. The whole table shows how much more pollution the water would stand before oxygenation would cease.

II 21-11-27

Wind E, moderate

Tide—Slack, at end of ebb

Temperature of water, 27° C

Sewage had been discharging many hours

It was intended to investigate the northern end of the zone, but so many banks were uncovered that the launch could not cope with the projected investigation. However, the results obtained are as follows—

TABLE II

Origin of Sample	Plate Count	Cl Content	Cl Content	O ₂ Saturation %
		Parts per 10 ⁶	Parts per 10 ⁶	
1 Centre of zone	Uncountable	6.0	15 x 10 ⁶	87
2 50 yds east	Very low	6.6	20 x 10 ⁶	100
3 100 yds south	17,000	5.5	20 x 10 ⁶	83
4 200 yds south	9,600	5.45	20 x 10 ⁶	82
5 400 yds south	12,000	3.05	20 x 10 ⁶	23
6 600 yds south	4,000	5.3	20 x 10 ⁶	81
7 Lighthouse	1,720	6.0	20 x 10 ⁶	92
8 Lytton	10	6.15	20 x 10 ⁶	97
9 Pinkenba Wharf	300			

See Map 3 (Text-figure 2)

All these samples were taken within 30 yds of the shore of the sewage reserve, and still show rapidly diminishing pollution owing to dispersion and oxidation. It will be noted that the pollution at Pinkenba wharf is almost as bad as that 400 yds south from the outfall after a two-hours' "run" on a flood tide. The oxygen content still remains high enough to deal effectively with the pollution.

III. 8-12-27

Wind E, strong

Tide—

Half hour before end of ebb at beginning of experiment.

Slack at end of ebb at end of experiment.

Temperature of water 26° C

Sewage running two and a-half hours

Table IIIA deals with samples taken within 20 yds of the shore to the north of the outfall

Table IIIB deals with samples taken just off the shore

TABLE IIIA

Origin of Sample	Plate Count per 1 c c	O ₂ Content Parts per 10 ⁶	Cl Content Parts per 10 ⁶	O ₂ Saturation %
1 50 yds north of centre of zone	Uncountable	1.2	20 x 10 ⁶	18
2 100 yds north of centre at edge	Uncountable	1.0	20 x 10 ⁶	15
3 100 yds north of centre over edge	700	1.5	20 x 10 ⁶	22
4 200 yds north	800		20 x 10 ⁶	
5 300 yds north	600	2.5	20 x 10 ⁶	37
6 400 yds north	700	2.2	20 x 10 ⁶	33
7 450 yds north	700	2.6	20 x 10 ⁶	40
8 500 yds north	300	3.9	20 x 10 ⁶	59
9 550 yds north	60	7.0	20 x 10 ⁶	100
10 600 yds north	500	4.3	20 x 10 ⁶	65

See Map 4, which shows area of investigation set out in Tables IIIA and IIIB (Text-figure 3)

TABLE IIIB

Origin of Sample	Plate Count per 1 c c	O ₂ Content Parts per 10 ⁶	Cl Content Parts per 10 ⁶	O ₂ Saturation %
1 100 yds north	Uncountable	1.0	30 x 10 ⁶	C 17
2 200 yds north	600	1.2	30 x 10 ⁶	C 20
3 250 yds north	1 040	1.5	30 x 10 ⁶	26
4 300 yds north	500	2.0	30 x 10 ⁶	34
5 350 yds north	1,280		30 x 10 ⁶	
6 400 yds north	400	3.6	30 x 10 ⁶	62
7 450 yds north	150	5.0	30 x 10 ⁶	86
8 500 yds north	428	3.8	30 x 10 ⁶	65

See Map 4 (Text-figure 3)

The samples dealt with in Tables IIIA and IIIB were taken simultaneously and independently. They show that, on the ebb tide and with a strong easterly breeze, pollution is pretty uniform for a considerable distance northwards along the estuary, though the zone is extraordinarily narrow—not more than 25 yds.

The low oxygen saturation is striking and must evidently be a function of the shallowness of the water on the end of the ebb tide, probably due to evaporation and redissolution of inorganic salt from the silt, resulting in a greatly increased Cl content.

IV 20-3-28

Tide—Ebbing

Work commenced about 2.15 p.m.

Work finished at 2 45 p m
 Low water at 2 57 p m
 Sewer discharging six hours
 Wind S E by E fresh
 Temperature of water, 26° C

TABLE IV

Origin of Sample		Plate Count per 1 c c	O ₂ Saturation %
1	Southern end of " Zone" i.e., 40 yds south of outfall	2,280	60
2	Just at edge of zone, i.e., 40 yds south of outfall	1,224	86
3	20 yds off shore opposite outfall	1,480	77
4	Inside edge of zone (20 yds off shore), 100 yds north of outfall	784	81
5	200 yds north of outfall	1,040	92
6	300 yds north of outfall	896	88
7	400 yds north of outfall	1,000	90
8	500 yds north of outfall	1,520	87
9	600 yds north of outfall	760	88
10	700 yds north of outfall	964	Not taken
11	800 yds north of outfall	1,040	Not taken
12	900 yds north of outfall	1,280	86

It will thus be seen that—

1 On the ebb tide no sewage can travel any but a very short distance upstream. In this case the zone to the south of the outfall was very sharply defined and extended up stream only about 40 yds.

2 Under the influence of the wind and tide-stream the zone of pollution is very narrow, estimated at 25 yds at its maximum.

3 Owing to eddies the pollution is neither uniform nor uniformly graduated downstream. It is almost as heavy 900 yds north of the outfall as at the outfall, showing how thorough mixing must be under the influence of wind and tide.

4 The pollution is obviously very slight, only one plate showing a count of over 2,000 organisms per 1 c c.

5 The pollution is indeed so slight that the oxygen saturation (which is an index of the sterilising power of the water) was reduced at its lowest, by only one-third. In all cases it still remained very high indeed. So that even in the polluted area the water still retained a very high proportion of its sterilising power.

V 14-4-28

Wind S W, light

Tide—

Ebbing

Low water, 11 5 a m

Work started at 10 45 a m

Work stopped at 11 8 a m

Sewage discharging 16 hours up to 10 a m

TABLE V

Origin of Sample	Plate Count per 1 c c	Chloride Content	O ₂ Satura- tion %
	Parts per 10 ⁶	Parts per 10 ⁶	
1 Beacon A*	2,080	15 x 10 ³	88
2 50 yds north of beacon A	2,800	15 x 10 ³	81
3 100 yds north of beacon A	3,080	15 x 10 ³	85
4 150 yds north of beacon A	2,320	15 x 10 ³	88
5 200 yds north of beacon A	3,520	15 x 10 ³	88
6 250 yds north of beacon A	2,360	15 x 10 ³	80
7 300 yds north of beacon A	1,440	15 x 10 ³	88
8 350 yds north of beacon A	1,160	15 x 10 ³	82
9 400 yds north of beacon A	1,200	15 x 10 ³	74
10 450 yds north of beacon A	1,320	15 x 10 ³	86

Just before this investigation, sewage had been running into the estuary from within 2 hours 20 mins of low tide on the night of 13-4-28, continuously through the flood tide from 9 24 p m that evening until the "turn" at 4 1 a m on 14-4-28, and continued on the ebb until stopped at 10 a m, 14-4-28, about an hour before low water

VI Table VI shows plate counts of samples of water taken within 25 yds of the shore with the wind slightly onshore. The average depth of the water was about 3 ft 6 in. The plate counts are all very low and the O₂ saturation always remains high

14-4-28

Wind S E, fresh— i e, blowing onshore

Tide—Flood (2 hours 10 min after turn)

Work started at 1 15 p m

Work finished at 1 50 p m

Sewage stopped discharging after 16 hours run up to 10 a m

14 4-28 (See Table V)

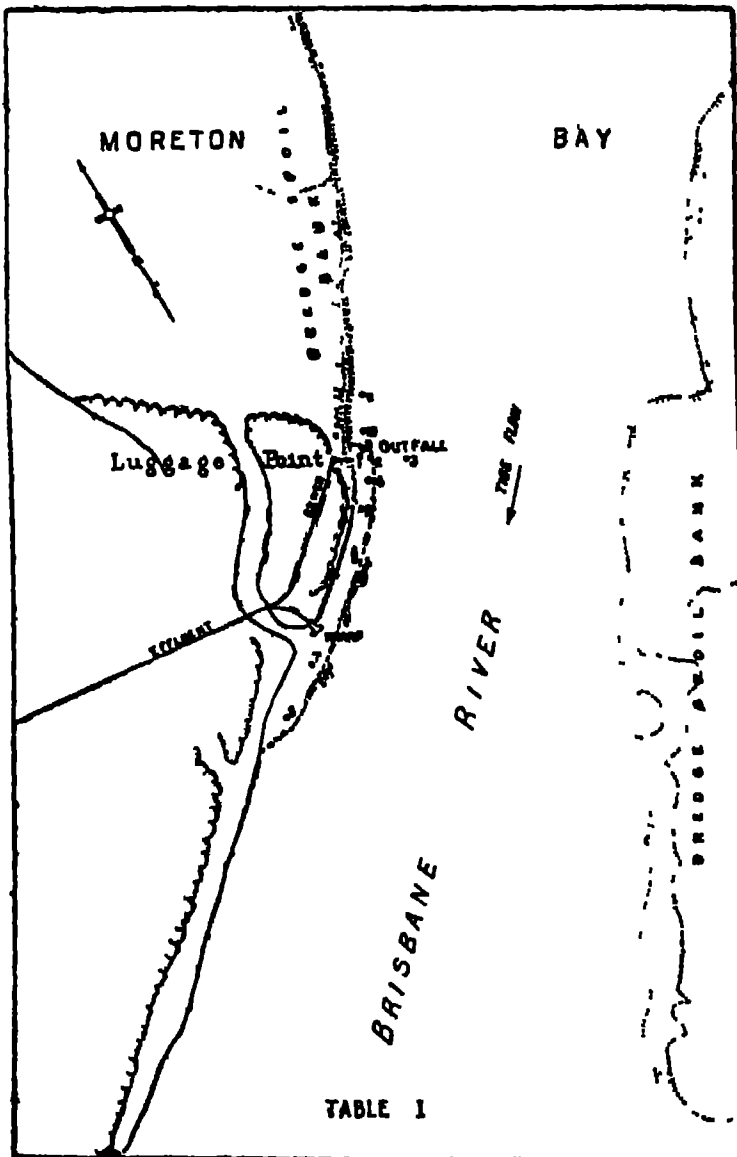
TABLE VI

Origin of Sample	Plate Count per 1 c c	Chloride Content	O ₂ Satura- tion %
	Parts per 10 ⁶	Parts per 10 ⁶	
1 200 yds south of beacon A*	1,000	20 x 10 ³	84
2 500 yds north of outfall	See † note	20 x 10 ³	81
3 400 yds north of outfall	210	20 x 10 ³	89
4 300 yds north of outfall	990	20 x 10 ³	85
5 Outfall	10,080	20 x 10 ³	85
6 100 yds south of outfall ..	840	20 x 10 ³	84
7 200 yds south of outfall	1,120	20 x 10 ³	86
8 300 yds south of outfall	960	20 x 10 ³	90
9 400 yds south of outfall	840	20 x 10 ³	89
10 500 yds south of outfall	760	20 x 10 ³	86

* Beacon A is about 900 yards N of the outfall

† Sample II was contaminated by tap water during manipulation, and colonies of *B. subtilis* vitiated the accuracy of the plate count

From this table it seems reasonable to assume that considerable sterilisation has taken place downstream, but that also some portion of the sewage remains as a residue in the zone at the outfall and is washed upstream on the flood tide



Text figure 1

Subcultures were made of colonies selected at random from plates inoculated from water which is treated in Tables V and VI. Two plates yielded lactose-fermenting organisms, but their distribution was so capricious I think it quite possible that similar organisms could be found in other situations. It must, however, be stated that the organisms

which predominated most definitely in plates made from water at a distance from the outfall were fluorescent bacilli which did not ferment lactose but invariably fermented dextrose, and capable apparently of longer survival than those organisms usually regarded as significant of faecal contamination

VII 17-4-28

Wind S E, fresh

Tide—Ebbing

Low water 1 39 p m

Work started at 12 15 p m

Work finished at 12 45 p m

Sewage discharging up to 11 30 a m

Temperature of water 18° C

TABLE VII

Origin of Sample		Plant Count per 1 c c	Chloride Content	O ₂ Saturation %
		Parts per 10 ³	Parts per 10 ⁶	
		Parts	per 10 ⁶	
1	30 yds south of outfall	900	15 x 10 ³	Not < 90
2	Outfall	500	15 x 10 ³	Not < 90
3	20 yds east of outfall	300	15 x 10 ³	Not < 90
4	50 yds north of outfall	600	15 x 10 ³	Not < 90
5	100 yds north of outfall	700	15 x 10 ³	Not < 90
6	200 yds north of outfall	450	15 x 10 ³	Not < 90
7	300 yds north of outfall	800	15 x 10 ³	Not < 90
8	400 yds north of outfall	1,300	15 x 10 ³	Not < 90
9	500 yds north of outfall	880	15 x 10 ³	Not < 90
10	600 yds north of outfall	570	15 x 10 ³	Not < 90
11	700 yds north of outfall	320	15 x 10 ³	92
12	800 yds north of outfall	400	15 x 10 ³	Not < 90

All of these samples were taken close inshore (average distance from sandspit 25 yds)

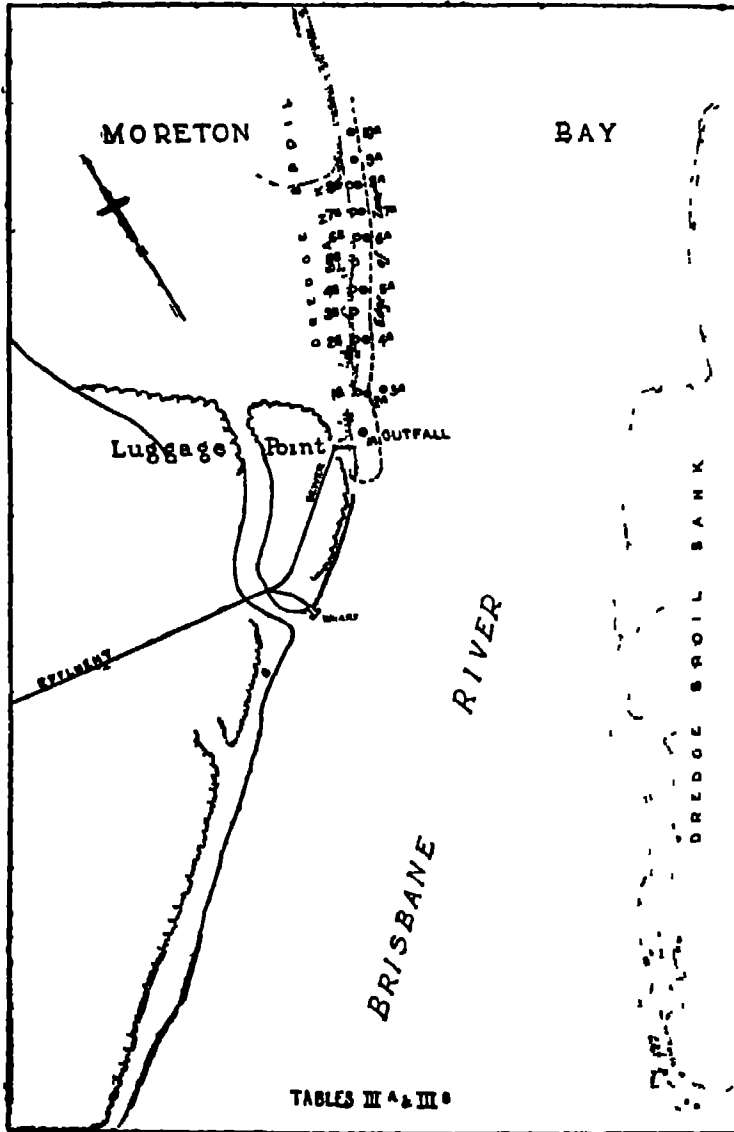
Random samples were taken of suspicious colonies for the presence of lactose fermenters, and these appeared in one sample in four on an average. One sample incidentally yielded a streptococcus which is receiving special bacteriological attention

(D) Standards to regulate sewage disposal are surprisingly few, probably for the reason that the relevant factors vary within such wide limits. As I noted in the beginning, it would seem that so far each system must be designed largely in accordance with favourable conditions.

All the literature I have access to seems to show that—

1 "If 50 per cent of the O₂ which a water can hold in solution is removed, it will not be offensive, but it can probably be distinguished from a well aerated water by those familiar with such conditions. It is desirable to maintain an oxygen content in streams and natural waters somewhat higher than 50 per cent.

" 70 per cent saturation of O_2 would be a satisfactory limit to set as a criterion to determine the limit of pollution permissible in a stream " [2]



Text-figure 3

2 The report of the "International Joint Commission on the Pollution of Boundary Waters" (1914) [3] seems to be concerned almost solely with inland streams and with the possible contamination of drinking water supplies, so that Clause 5 of their findings must apply more cogently still to estuaries. With respect to inland waters this Commission finds that, "In waterways where some pollution is inevitable and where the ratio of the volume of water to the volume

of sewage is so large that no local nuisance can result, it is our judgment that the method of sewage disposal by dilution represents a natural resource and that the utilisation of the resource is justifiable for economic reasons, provided that an unreasonable burden or responsibility is not placed upon any water purification plant and that no menace to the public health is occasioned thereby "

The International Commission therefore believes that in certain conditions a simple dilution system of sewage disposal is adequate even when the diluting water may be required for human consumption.

3 The Eighth Report of the Royal Commission on Sewage Disposal (1912) [4] was apparently also addressed to pollution of inland streams and the only relevant portion of its findings is that "with a dilution of over 500 volumes all tests may be dispensed with and crude sewage discharged, subject to such conditions as to the provision of screens or detritus tanks as might appear necessary to the central authority "

4 Metcalf and Eddy [3] quote Dr Dunbar, "Principles of Sewage Treatment " He says, "The question of sewage disposal is intimately bound up with that of spreading epidemics by means of polluted rivers," (i.e., by drinking, bathing, infection of sea food), "and measures to be adopted can only be decided upon after due consideration of all local conditions "

5 Colonel Longley's standards (2) do not seem universally acceptable The Metropolitan Sewerage Commission of New York advised a minimum of 4.3 parts O_2 per million in New York Harbour equal to 58 per cent saturation Mr Fuller reported to his Board on this finding that he considered this standard needlessly high He considered roughly 2.1 parts O_2 per million a safe lower limit under proper conditions, these being that sewage sludge shall not be allowed to accumulate to such an extent as to become a serious factor in absorbing O_2 from the water

6 Many other authorities agree that no uniform standard can at present be laid down O_2 is a rough guide, but local conditions should be taken into account

DISCUSSION

There is no reason for believing that Luggage Point sewage outfall and treatment station are now or can be a nuisance The determination of a nuisance is a function of the normal sense of smell I and my assistants in this investigation did not detect any offensive smell at any point of the sewage line, excepting perhaps a more than fairly perceptible one just above the incoming sewage flow at the Luggage Point pumping station

This finding could have been forecasted from a consideration of the system I should expect to find a more intense odour higher up the system than at Luggage Point, since by the time sewage reaches the treatment works oxidation and mechanical division of sewage has taken place

'After discharge into the estuary the sewage still has a high bacterial content. From a review of the tables it seems evident that dilution, dispersion and destruction of faecal organisms are very rapid. The tables show that pollution of a very narrow strip of the estuary is small, no greater indeed than that of most inland streams or than that of large watercourses flowing through cities.

In the Brisbane estuary the polluted strip of water is relatively narrow, of the order of about one-thirtieth of the width of the total available diluent.

I found that shortly before and at low water, i.e., soon after the period most suitable for discharge, the depth of the polluted zone varied within very narrow limits—from zero to a maximum of 4 ft. 6 in.

The reason for this is almost solely because the winds prevailing in the estuary for periods other than those of the short infrequent westerly winds come from the easterly side of the compass and tend to drive the sewage onshore.

This fact raises an interesting question. Since the public are terribly frightened of germs, it seems that our duty is to destroy them, at least those that come down in sewage. This is a great pity, because sewage is incomparably the best fertiliser we have, and Chinese society has a distinct advantage because it uses sewage to enrich its agricultural yield. Since, however, we have decided to destroy as well as we can our nitrifying bacteria by heavy dilution and consequent dispersion and oxidation, we should make a thorough job of it.

In the case we are investigating we see that quite a considerable amount of the bacterial content of the sewage is blown onshore. It is evident that on a receding tide quite a considerable number of organisms must be deposited in the silt. Here they die when exposed to the sun or are washed off again and destroyed by the incoming tide. If this silt is not to be used as manure, as it could be, and if these really beneficent germs frighten good citizens, the complete job of their destruction would best be accomplished by using the deep water more than 30 yds offshore for their final discharge. At present it is very evident from the maps and tables that the work of bacterial destruction could better be accomplished by continuing the outfall sewer into much deeper water than that into which it now discharges.

Even now it is evident that sewage pollution of the estuary is very low. It can be dangerous only if the salt water about half-a-mile above and below the outfall is used as drinking water or if sea food taken within that range is consumed. Even in the present state of the law which permits the sale of oysters and fish taken on foreshores immediately adjacent to the outfall, infection of the population in this way is a matter of pure chance, as my discussion of the tables shows. Our samples show that in a very high percentage of cases in which sewage discharge is regulated to produce the best hygienic results no faecal contamination can be detected.

CONCLUSIONS.

1 The present method of disposal of sewage into the Brisbane estuary is not a nuisance

2 The sewage as discharged into the estuary contains solid matter only in a very finely divided state

3 The bacterial content of the sewage is reduced with very great rapidity

4 The total power of the water of the Brisbane estuary to render sewage innocuous is many multiples of that required at present

5 The volume of water in the Brisbane estuary can effectually sterilise at a minimum twenty four hours' effluent within a time estimated at four hours from cessation of discharge at the outfall even at a maximum depth of 4 ft of water

6 Shallow water is not as good a diluent for sewage as deep water

7 Onshore winds blowing on shallow water hinder dispersion and dilution

8 Sewage disposal into the Brisbane estuary would be greatly improved by continuation of the outfall into deeper water. The optimal length of this continuation would be a function of the grade of the channel, and could only be determined by sounding experiments. From my investigations I conclude it should be not less than 50 yds

9 At present the method of disposal is economically sound and perfectly safe provided that no shell fish is taken for human consumption from the shore 800 yds above and below the outfall sewer, at a distance of 50 yds from high-water mark

10 The most perfect hygienic result can be obtained by sewage discharge lasting from the end of flood tide until within an hour of the end of the ebb tide

11 All these conclusions may be altered by large increases in volume of discharge

I must here record my thanks to Mr Manchester (Chief Engineer, Water Supply and Sewerage Department, Brisbane City Council) for permission to publish these findings, to Mr Thom (Sewerage Engineer) for advice, to Mr Chamberlain for his assistance in chemical and field work and for arranging my itineraries, to the draughtsmen of the Sewerage Engineer's Department for so carefully preparing maps and diagrams, and to the staff of my laboratory for technical assistance —

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- 1 Whipple, G C, and Whipple, M C (1911)—Solubility of Oxygen in Sea Water *Jl Am Chem Socy*, 33, 362-365
- 2 Longley, F F (1922)—Report to Federal Quarantine Department on Sewage Pollution of Streams
- 3 Metcalf and Eddy—American Sewerage Practice, Vol III—"Disposal of Sewage"—pp 32-36 (quoted by Longley)
- 4 Royal Commission on Sewage Disposal, 8th Report (1912)

Cinnamomum Laubatii—the Chemical Characters of the Essential Oils of Leaves and Bark.

By T G H JONES, D Sc, A A C I, and F B SMITH, B Sc, F I C

(Read before the Royal Society of Queensland, 30th April, 1928)

Cinnamomum Laubatii (NO Lauracea) is described as a medium to large timbered tree, with leaves dark green above, inclined to whitish beneath, three to six inches long and one to two inches wide, with a prominent midrib, and two lateral veins arising from the base more or less parallel to the midrib and ascending to one-third of the apex. The flowers are borne in auxiliary panicles and the fruit is a berry seated in a somewhat enlarged perianth tube.

The *Cinnamomums* of Australia have been described by R T Baker [1], who establishes the specific rank of four Australian varieties, namely, *C. Oliveri*, *C. Laubatii*, *C. virens*, *C. propinquum*, distinguishing particularly *Cinnamomum Laubatii* from the Indian *Cinnamomum Tamala*, with which it had been previously considered identical [2, 3, 4].

Baker's determinations rest primarily on comparison of botanical features of authenticated specimens, but he further attempts to contrast chemical characters of essential oils and to correlate these with leaf venation and anatomy of the bark.

In his prosecution of this intention in relation to the Australian *Cinnamomums*, certain of Baker's assumptions on the chemical side appear unfounded.

The essential oils of penniveined *C. Oliveri* it is true are camphoraceous [5, 6], but as the present authors show, and contrary to Baker's assumption, those of penniveined *C. Laubatii* are not. Again, there appears no warrant for regarding *C. virens* as non-camphoraceous, and that the oils of the uninvestigated *C. propinquum* will be camphor-free is admittedly assumed on the ground of the trinervate character of the leaf.

Co-relation of the chemical characters of the essential oils of the Australian *Cinnamomums* with anatomical habit appears therefore to be unreliable. Nevertheless the specific independence of *C. Laubatii* and *C. Tamala* is fully borne out by the distinct characters of their essential oils. The leaf oil of *C. Tamala* consists largely of eugenol [7].

1 Aust Assoc Adv Sc, vol xii, 1912

2 Benthams, Flora Australiensis, vol v, p 303

3 Ewart, Proc Roy Soc Vic., vol xix

4 Bailey, Queensland Flora, 1901, part iv, p 1308

5 H G Smith, Proc Linn Soc NSW 1897, p 277

6 Hargreaves, J C S, 1916, 109, 751

7 Schummel and Co Report, April 1910

The essential oils of *C. Laubatu* are shown by the present examination to be mainly sesquiterpene and sesquiterpene alcohol associated in the bark oil with safrol and in the leaf with terpenes and a small amount of cineol. No trace either of camphor or eugenol could be detected in the oils, which must therefore be regarded as non-camphoraceous and of little commercial value.

EXPERIMENTAL

The material, verified as authentic, was supplied by the Provisional Forestry Board, Brisbane, from the Atherton Forest Station.

On distillation in steam—

60 lb of crushed bark yielded 40 grammes oil (15 per cent)

120 lb of crushed leaves yielded 70 grammes oil (13 per cent)

The small yields of oil (contrasting sharply with those from *C. Oliveri*) prevented complete and detailed examination of minor constituents, but the amounts available sufficed to demonstrate their main features. Both oils possessed agreeable odours, that of the bark suggesting safrol.

The following constants were determined (those of *C. Tamala* being included for comparison) —

	<i>C. Laubatu</i>		<i>C. Tamala</i>
	Bark oil	Leaf oil	Leaf oil
d_{20}^{20}	9470	9625	1 0257
$[a]_D^{20}$	+ 13	+ 8.5	+ 16.37
n_D^{20}	1.485	1.4848	1.5259
Ester value	10	18	Not available
Acetyl value	39	63	Not available

Agitation with appropriate reagents served to show in each oil absence of any but traces of phenols or extractable aldehydes or ketones.

EXAMINATION OF THE BARK OIL

Thirty cubic centimeters of oil were fractionally distilled at 28 mm pressure, only a few drops of oil distilled below 140 deg C. The following fractions were collected —

(a)	0° - 140° C	1 cc				
(b)	140° - 150° C	5½ ccs	$[a]_D^{20}$ + 11.5	d_{20}^{20} 9600, n_D^{20}	1.5005	
(c)	150° - 160° C	12 ccs	$[a]_D^{20}$ + 17.5	d_{20}^{20} 9312, n_D^{20}	1.5005	
(d)	above 160° C	4 ccs	$[a]_D^{20}$ + 20	d_{20}^{20} 9408, n_D^{20}	1.5005	

leaving a small darkened residue in the flask.

Fraction (a) was too small for examination, but apparently consisted of a small amount of terpene.

Fraction (b) smelt strongly of safrol, the presence of which was determined by the formation of safrol nitrosite (M.P. 129 deg C). The density of the fraction indicated a safrol content of not more than 50 per cent, the remainder being sesquiterpene.

Fraction (c) —This fraction constituted the greater part of the oil, and as preliminary analysis indicated the presence of a sesquiterpene it was repeatedly distilled over metallic sodium, being finally obtained as a pale-yellow liquid with the following constants—

B P	150-155° C	(26 mms)		
d_{20}^{25}	9242,	$[\alpha]_D + 16$	n_D^{20}	1.5005
[Found C = 88% H = 11.6 C ₁₅ H ₂₄ requires C = 88.2 H = 11.8]				

Fraction (d) was essentially sesquiterpene together with a small amount of sesquiterpene alcohol.

The bark oil therefore contained safiol and a sesquiterpene, together with smaller amounts of ordinary terpene and sesquiterpene alcohol

EXAMINATION OF THE LEAF OIL.

Fifty cubic centimeters of oil were fractionally distilled at 28 mms pressure, and the following fractions collected —

(a)	0 - 110° C	5 ccs	d_{20}^{25}	8792	$[\alpha]_D + 2.5$
(b)	110 - 150° C	6 ccs	d_{20}^{25}	9340	$[\alpha]_D + 4.5$
(c)	150 - 160° C	18 ccs	d_{20}^{25}	9386	$[\alpha]_D + 14$
(d)	above 160° C	6 ccs	—	—	—

leaving an appreciable residue (15 ccs) resinified in the distilling flask

Fraction (a) was extracted with 50 per cent resorcin solution and an absorption of 1 cc (20 per cent) occurred. The resorcin solution, on being examined in the usual way, gave a small quantity of cineol identified by formation of its iodol compound. The unabsorbed oil 4 ccs evidently consisted of a mixture of terpenes. Negative tests were recorded for pinene, limonene, and phellandrene. The small amount available prevented further examination.

Fraction (b) consisted mainly of a mixture of (a) and (c)

Fraction (c) consisted of almost pure sesquiterpene, repeated distillation over sodium causing little diminution in volume. The purified substance possessed the following constants —

B P	152-155° C	26 mms		
d_{20}^{25}	9302	$[\alpha]_D + 16$	n_D^{20}	1.5015
[Found C 88.1 H 11.5 C ₁₅ H ₂₄ requires C 88.2 H 11.8]				

Fraction (d) was mainly sesquiterpene with some sesquiterpene alcohol

The leaf oil therefore consisted of lower terpenes, some of cineol and a considerable proportion of sesquiterpene and accompanying sesquiterpene alcohol

The similarity of physical constants suggests that the sesquiterpenes present in both oils are identical

Both gave usual colour reactions with bromine vapour and with concentrated sulphuric acid characteristic of many sesquiterpenes of the Australian flora

A Revision of Four Genera of Australian Scelionidae.

By ALAN P. DODD

(Read before the Royal Society of Queensland, 28th May, 1928)

This paper revises the Australian species of the genera *Hoploteleia* Ashmead, *Anteromorpha* Dodd, *Styloteleia* Kieffer, and *Phænoteleia* Kieffer of the family Scelionidae (Hymenoptera Proctotrypoidea), three species of *Hoploteleia* and one species of *Phænoteleia* are described as new.

The genus *Hoploteleia* occurs throughout the world, *Styloteleia* and *Phænoteleia* were not formerly recognised outside the Philippine Islands, *Anteromorpha* is common to Australia and the Hawaiian Islands.

Except in the case of the species of *Hoploteleia*, which are parasitic in the eggs of long-horned grasshoppers (*Tettigoniidae*), the host relations of these insects are unknown.

STYLOTELEIA KIEFFER

Broteria, vol. 14, p. 184 (1916)

Female, *Male*.—Head, from dorsal aspect, transverse, about twice as wide as long, descending sharply to the occipital margin which is almost straight from frontal aspect circular, lower frons faintly depressed and with a median carina, cheeks broad, mandibles tridentate, maxillary palpi 4-jointed, eyes large, bare, lateral ocelli against the eye margins. Antennae 12-jointed, in the female with a stout 5-jointed club, in the male the flagellum filiform, the joints moderately long. Thorax, from lateral aspect, plainly longer than high, almost flat dorsally, pronotum hardly visible from above, scutum large, the anterior margin rather broadly rounded, the median lobe anteriorly with a small area separated posteriorly by a delicate transverse carina, parapsidal furrows complete and distinct, scutellum twice as wide as long, its posterior margin truncate or somewhat concave, metanotum in the male very transverse, not armed or prominent, its posterior margin straight, propodeum in the male moderately short, its posterior margin gently concave, without median or lateral carinae, armed medially with a pair of well separated stout teeth, the posterior angles faintly acute, metanotum and propodeum in the female broadly flattened or depressed, and hidden by the abdominal prominence, the propodeum on either side and wide apart with a delicate carina which may be raised at base in the form of a short tooth. Forewings long and broad, reaching the

apex of the abdomen in the male, or failing by a little in the female, submarginal vein with a downward curve before joining the costa, marginal vein one-half to two-thirds as long as the stigmal, which is long and very oblique, postmarginal vein one-half longer or twice as long as the stigmal, basal and median veins indicated by brown lines. Legs slender, posterior tarsi no longer than their tibiae, their basal joint longer than 2.5 combined. Abdomen slender, somewhat narrowed at base, in the female one and two-thirds to twice as long as the head and thorax united, elongate, fusiform, narrowly acuminate at apex, segment 1 not petiolate or subpetiolate, armed with a large stout horn that projects over the propodeum and metanotum or even over the posterior portion of the scutellum, 2 and 3 a little longer than 1 or 4, 6 as long as or longer than 4 and 5 united, transversely impressed or subdivided toward the middle and having the appearance of two segments, so that the abdomen appears to contain seven segments, in the male the abdomen is one half to two-thirds longer than the head and thorax united, consisting of eight segments, 6 somewhat shorter than 5, the apical two segments very short and transverse.

Type — *S. rufescens* Kieffer, *Broteria*, vol 14, p 185 (1916)

This genus was erected for the above species from the Philippine Islands. Through the courtesy of the late C. F. Baker, of Los Banos, Philippine Islands, I have had the opportunity of examining a paratype of *rufescens*, and am thus able to include three Australian species in the genus.

Styloteleia contains long slender insects with the general appearance of species of *Macroteleia* Westwood and elongate forms of *Baryconus* Foerster, from both of which genera it may be distinguished by the downward curve of the submarginal vein, and in the female by the apparent division of the apical abdominal segment. The abdomen is less narrowed at base than in *Baryconus*, and is not subpetiolate. The strong teeth on the propodeum are much larger than in certain species of *Baryconus*, where they are merely basal elevations of the median carinae. The three Australian species are very similar.

STYLOTELEIA ACUTIVENTRIS DODD

Trichoteleia acutiventris Dodd, *Royal Soc. of Qld.*, vol 26, p 98 (1914)

Trichoteleia novæ-hollandiæ Dodd, *Archiv. für Naturgeschichte*, Berlin, vol 80 (1915)

Female — Length, 3.20 mm

Head black, thorax rich orange red, darker on the sides, the median lobe of the scutum mostly black, abdomen deep red, the apical segment blackish, the basal horn bright orange, legs bright golden yellow, the coxæ dusky, antennal scape and pedicel golden yellow, the funicle joints brownish yellow, the club black.

Vertex and upper frons with a few scattered fine punctures bearing fine hairs, a line of similar punctures on either side of frons against the eyes, cheeks with strong striæ converging towards mouth, smooth above

except for a few punctures, vertex between the eyes rather wide, the lateral ocelli plainly farther from each other than from the median ocellus. Antennal scape moderately long, pedicel twice as long as its greatest width, funicle joints as wide as the pedicel, 1 slightly longer than the pedicel, 2 distinctly shorter than 1, 3-5 gradually shortening, 5 as wide as long, club 5-jointed, 1-4 each twice as wide as long, 3 slightly the widest. Thorax from dorsal aspect one-third longer than its greatest width, scutum stout, smooth, with a few rather small scattered punctures bearing fine hairs, parapsidal furrows coriaceous, wide apart, separated posteriorly by about two-thirds their length, scutellum with fine pubescence and a few punctures, its posterior margin gently concave, propodeum at base on either side of the abdominal horn with a stout upright tooth. Forewings failing by a little to reach apex of abdomen, somewhat brownish, the infuscation tending to form a longitudinal stripe, marginal vein two-thirds as long as the long oblique stigmal vein, the postmarginal twice as long as the stigmal, basal and median veins represented by thick brown lines. Abdomen twice as long as the head and thorax united, four times as long as its greatest width, segment 1 somewhat narrowed at base, almost as long as its posterior width, with a large stout horn projecting over the propodeum, 2 one-fourth longer than 1, 3 as long as 2, no longer than wide, 4 two-thirds as long as 3, 5 two-thirds as long as 4, 6 somewhat longer than 4 and 5 combined, the basal portion one-half as long as the narrow apical portion, 1 strongly striate, its horn smooth, 2 strongly striate, the striae irregular except laterally, the surface between densely rugulose, 3 densely reticulate-rugulose, with several striae laterally, 4 with similar sculpture but rather broadly smooth on posterior half medially, 5 and basal portion of 6 with a smooth median path, on either side with numerous pubescent punctures and fine surface sculpture, apical portion of 6 with fine striae and pubescence, lateral margins of segments with fine pale hairs.

Male —Length, 2.70 mm

Scutum anteriorly with a few more punctures than in the female, posterior margin of scutellum straight, teeth of propodeum triangular, their inner margins oblique and almost meeting at base, their outer margins straight, their surface with two strong striae. Abdomen two-thirds longer than the head and thorax united, sculpture failing medially on segments 4 and 5 and posterior half of 3, 6 with similar sculpture to 5, 7 and 8 very short. Antennal scape yellow, the pedicel dusky, the flagellum black, pedicel one-third longer than its greatest width, funicle 1 twice as long as wide, subequal to 5, 3 slightly the longest, 4-9 gradually shortening.

Habitat —North Queensland Cairns district (type), one female, two males in August and September (A P D), Dunk Island, one male in August, H. Hacker.

Type —South Australian Museum, I 11012

The male was originally described as a distinct species.

STYLOTELEIA NIGRICINCTA Dodd

Trichotelia nigrincincta Dodd, Archiv für Naturgeschichte, Berlin, vol 80, (1915)

Female —Length, 2.40 mm

Head black, thorax rich orange-red, the median lobe of the scutum dusky, abdomen dull orange, dusky-black at base, apex, and along lateral margins, the basal horn bright orange, legs, including the coxæ, golden-yellow, antennæ golden-yellow, the club black

Vertex between the eyes not as wide as in *acutiventris*, the lateral ocelli as far from the median ocellus as from each other, vertex from the median ocellus to the occiput with numerous rather small punctures bearing fine setæ, frons smooth, the upper frons with a few scattered punctures, and a line of punctures against the eye margins, cheeks striate and with numerous punctures, the upper cheeks showing impressed reticulation. Pedicel twice as long as its greatest width, funicle joints narrower than the pedicel, 1 as long as the pedicel, 2 shorter than 1 but twice as long as wide, 3 slightly shorter than 2, 4 plainly shorter than 3, 5 as wide as long, club 5-jointed, 1-4 each twice as wide as long, 1 rather small, 3 slightly the widest. Thorax one half longer than its greatest width, median lobe of scutum with numerous small punctures, the lateral lobes with scattered punctures, parapsidal furrows separated posteriorly by one-half their length, scutellum with a few fine punctures, its posterior margin almost straight, propodeum at base on either side of the abdominal horn with a short blunt tooth. Forewings distinctly brownish, marginal vein hardly one-half as long as the long stigmal vein, the postmarginal two-thirds longer than the stigmal, basal and median veins represented by thick brown lines. Abdomen a little less than twice as long as the head and thorax united, four times as long as its greatest width, segment 1 as long as its posterior width, with a large stout horn projecting over the propodeum, 2 scarcely longer than 1, 3 as long as 2 three-fourths as long as wide, 4 two thirds as long as 3, 5 two-thirds as long as 4, 6 somewhat longer than 4 and 5 united, the basal portion one-half as long as the narrow apical portion, 1 striate, its horn circularly striate at base, smooth for the most part, 2 rather finely irregularly striate and densely finely reticulate, 3 and 4 with the striæ less distinct and giving way to the reticulate sculpture, which is inclined to fail medially on 4, 5 and basal portion of 6 with a smooth median path, on either side weakly reticulate with a few punctures, apical portion of 6 with fine striæ and pubescence

Male —Unknown

Habitat —North Queensland Cairns district, the type female in February, A. P. Dodd

Type —South Australian Museum, I 11109

Very similar to *acutiventris*, but smaller, the vertex narrower between the eyes and with more numerous punctures, the funicle joints

more slender than the pedicel, the posterior margin of the scutellum not definitely concave, the stræ less strong on segments 1 and 2 of abdomen, and the marginal vein shorter in relation to the stigmal vein

STYLOTELEIA TERRÆ-REGINÆ Dodd

Trichotelma terra-reginae Dodd, Archiv für Naturgeschichte, Berlin, vol 80, (1915)

Female—Length, 3.10 mm

Black, the sides of the thorax and the abdomen somewhat brownish, legs golden-yellow, the coxae somewhat darker, antennal scape golden-yellow, the pedicel and funicle joints brownish-yellow, the club black

Vertex between the eyes rather broad, the lateral ocelli nearer to the median ocellus than to each other, upper frons and vertex between the ocelli smooth with a very few scattered punctures, behind the ocelli to the occiput the punctures are rather dense, lower frons smooth, with a row of punctures against the eyes, cheeks with scattered punctures, lower cheeks and frons against the mouth with converging stræ. Pedicel twice as long as its greatest width, funicle joints scarcely narrower than the pedicel, 1 a little longer than the pedicel, 2-5 gradually shortening, 5 as wide as long, club stout, compact, 5-jointed, 1-4 each fully twice as wide as long. Thorax one half longer than its greatest width, scutum with scattered punctures on the median lobe, the lateral lobes smooth, parapsidal furrows punctate, separated posteriorly by less than one-half their length, scutellum with a few punctures, its posterior margin definitely concave, carinae on either side of propodeum not raised at base in the form of teeth. Forewings very lightly stained, marginal vein two-thirds as long as the long stigmal, the postmarginal one-half longer than the stigmal, basal and median veins marked by thick light brown lines. Abdomen twice as long as the head and thorax united, about five times as long as its greatest width, segment 1 fully as long as its posterior width, with a large stout horn projecting over the propodeum, 2 somewhat longer than 1, 3 as long as 2, as long as wide, 4 a little shorter than 3, 5 two-thirds as long as 4, 6 no longer than 4 and 5 united, the basal portion one half as long as the apical portion, 1 strongly striate, its horn smooth but circularly striate at base, 2 and 3 rather strongly striate, rugulose between the stræ, 4 and 5 with similar sculpture but the stræ are weaker and the median line is almost smooth, basal portion of 6 smooth at the median line, on either side with dense punctures, the apical portion with fine stræ and pubescence

Male—Length, 2.45 mm

Scutum and scutellum with the fine pubescent punctures rather more numerous than in the female, posterior margin of scutellum straight, propodeum longitudinally foveate medially, the teeth stout and blunt. Abdomen two thirds longer than the head and thorax united, segments 4 and 5 not smooth at the median line, 4 with scattered punctures posteriorly, 5 with scattered punctures between the stræ,

6 shorter than 5, rather densely punctate and pubescent, 7 and 8 very short. Antennal scape and pedicel yellow, the basal flagellar joints suffused with yellow, funicle 3 slightly the longest, 1 twice as long as wide, 9 hardly shorter than 1.

Habitat—North Queensland Cairns district, two females, one male in February and September, A P Dodd

Type—South Australian Museum, I 11154

Distinguished from *acutiventris* and *nigricincta* by its colour, absence of teeth on the female propodeum, and the stronger striation of the abdomen, and from *nigricincta* by the concave posterior margin of the scutellum, width of the vertex between the eyes, and sparser punctuation between the ocelli.

PHÆNOTELEIA KIEFFER

Broteria, vol 14, p 62 (1916)

This peculiar genus was erected to contain one species, *P. rufa* Kieffer, from the Philippine Islands. The discovery of a congeneric species from North Queensland is, therefore, of considerable interest. This insect has the general habitus of *Bayconus* Foerster, but the basal abdominal horn or process is greatly lengthened, extending for some distance into the mesoscutum and fitting into a deep margined channel, which cuts through the propodeum, metanotum, and scutellum, so that these sclerites are visible only laterally, when viewed from the side the outline of this process is continuous with the thorax. The submarginal vein has the downward bend, characteristic of *Styloteleia* Kieffer and *Anteromorpha* Dodd. The carinae on the propodeum appear to be the true lateral carina. The second abdominal segment is distinctly longer than the third and from lateral aspect is constricted at its base. The male of this genus is not yet known.

PHÆNOTELEIA CANALIS NEW SPECIES

Female—Length, 3.70 mm

Bright red-brown, the eyes and ocelli black, the abdomen dusky at apex, coxæ, trochanters, and femora bright yellow, the posterior coxæ and anterior femora brownish at base, the tibiæ and tarsi dusky-yellow, antennæ golden yellow, the club black.

Head from dorsal aspect less than twice as wide as long, the vertex posteriorly descending sharply to the occipital margin, from frontal aspect the head is circular, frons not depressed above the antennal insertion, cheeks broad, mandibles tridentate, eyes large, bare, ocelli large, close together, the lateral pair separated by their own diameter from the median ocellus and by less than one-half their own diameter from the eyes, head with fine pubescence, densely rather strongly reticulate-punctate and finely coriaceous, the sculpture with a transverse arrangement on lower half of frons, lower cheeks and the frons against

the mouth with converging striæ. Antennal scape moderately long and slender, its articulate joint long and slender, pedicel almost twice as long as its greatest width, funicle joints as wide as the pedicel, 1 almost twice as long as the pedicel, 2 two-thirds as long as 1, 2-5 gradually shortening, 5 as long as wide, club rather slender, 5-jointed, joints 1-4 about sub-equal, each slightly wider than long. Thorax from dorsal aspect one half longer than its greatest width, from lateral aspect about twice as long as high, flat above, pronotum narrowly visible on the sides, scutum almost as long as wide, broadly rounded anteriorly strongly reticulate-punctate and with fine pubescence, parapsidal furrows absent, scutellum present on either side of median channel, its posterior margin straight, its surface coriaceous and with a few punctures, metanotum present on either side as a small transverse concave plate, propodeum long, on either side with a lateral carina running from its base somewhat obliquely inwardly to join the margin of the median channel before the posterior margin. Posterior femora distinctly swollen. Forewings long but not reaching apex of abdomen, moderately broad, ciliation normal, lightly stained brownish, submarginal vein joining the costa at slightly more than one half the wing length, rather close to the costa except in its apical third where there is a distinct downward curve, marginal vein short, one fourth as long as the stigmal which is long and oblique, the postmarginal twice as long as the stigmal, basal and median veins indicated by light brown lines. Abdomen, without its basal horn, one-half longer than the head and thorax united, four times as long as its greatest width, a little narrowed at base, narrowing to apex, segment 1 twice as wide as long, produced anteriorly to merge with its process, which is very long, reaching almost to the middle of the scutum, slender, from lateral aspect not raised but continuing the direction of the segment, separated posteriorly from the segment by an oblique carina on either side, these carinae meeting sharply at the median line. 2 one third longer than its greatest width, sharply impressed or constricted at base, 3 three-fifths as long as 2, 4 a little shorter than 3, 5 as long as 4, 6 slightly shorter than 5, conical, almost twice as long as its basal width, abdomen bluntly rigid medially, segment 1 with two or three striæ on either side, transversely rugose at base, smooth posteriorly, the horn finely transversely striate but coarsely transversely rugose posteriorly, 2-4 longitudinally striate, finely sculptured between the striæ which are absent medially on 3, 4, and posterior third of 2, where the surface bears fine impressed reticulation, 5 and 6 with scattered pubescent punctures and fine striæ which fail medially on 5.

Male —Unknown

Habitat —North Queensland Dunk Island, one female in August
H Hacker

Holotype —In the Queensland Museum

ANTEROMORPHA Dodd

Royal Soc of S Australia, vol 37, p 145 (1913)

Female, Male —Head from dorsal aspect twice as wide as long, occipital margin concave, the frontal outline gently convex from eye to eye, from lateral aspect the frons and vertex are gently convex, the vertex posteriorly shortly declivous to the occipital margin, frons broad, hardly impressed above the antennal insertion, cheeks broad, eyes moderately large, wide apart, lightly pubescent, ocelli wide apart, the lateral pair touching the eye margins, mandibles large, bidentate, the teeth long and acute, maxillary palpi 4-jointed. Antennæ 12-jointed in both sexes, in the female the funicle joints short, the club 6 jointed, in the male the flagellar joints submoniliform. Thorax from lateral aspect much longer than high, almost flat above, from dorsal aspect one-half longer than its greatest width, pronotum narrowly visible laterally, scutum stout, its anterior margin broadly rounded, somewhat declivous anteriorly, parapsidal furrows absent, scutellum rather large, its posterior margin faintly convex, metanotum triangular, bluntly pointed at apex, about as long as its basal width, somewhat shorter than the scutellum, projecting as a flat tooth over the propodeum as far as or a little beyond its posterior margin, propodeum rather short, without lateral carinae, medially with a pair of well-separated carinae which curve sharply to form the almost straight posterior margin, the posterior angles in the form of short teeth, mesopleura with a large impression, metapleura with a cross furrow at half their length. Legs slender, posterior tarsi a little longer than their tibiae, their basal joint hardly as long as 2-5 united. Forewings extending to apex of abdomen, moderately broad, marginal cilia moderately short, discal cilia fine and dense, submarginal vein in its distal third curving away from before joining the costa, marginal vein shorter than the stigmal, which is long and very oblique, the postmarginal somewhat longer than the stigmal, basal and median veins hardly marked. Abdomen a little longer than the head and thorax united, twice as long as its greatest width, a little narrowed at base, blunt at apex, segment 1 sub-sessile, transverse, without a prominence in the female, 2 plainly longer than 1, 3 much the longest, somewhat longer than 1 and 2 or 4-6 united.

Type —*A. australica* Dodd

Among the Australian genera, in *Lapitha* Ashmead the abdomen is more petiolate, and segments 2 and 3 are almost subequal, in *Opsthaeantha* Ashmead the spine on the metanotum is simple, the abdomen is more petiolate, and the parapsidal furrows are complete, in *Chromoteles* Ashmead the parapsidal furrows are complete, and segments 2 and 3 of the abdomen are subequal. I have been unable to reconcile *Anteromorpha* with any of the genera given by Kieffer (1926), its distinguishing characters may be found in the absence of parapsidal furrows, form of the metanotum, subsequal abdomen with its long third segment, downward curving submarginal vein, and very oblique stigmal vein.

The Hawaiian species, *Opisthacantha dubiosa* Perkins (Fauna Hawaiiensis, vol 2, p 623, 1910) will fall in this genus I have seen an imperfect specimen, which is strikingly similar to *A. australica*, and may prove to be identical

ANTEROMORPHA AUSTRALICA Dodd

Royal Soc of S Australia, vol 37, p 146 (1913)

A. assimilis Dodd, ibidem, p 146

Female—Length, 1 50–1 80 mm

Head and thorax black, abdomen dull brown to brownish-black, legs golden-yellow, the coxae sometimes brown, antennal scape yellow, dusky at apex, the funicle joints fuscous, the club black

Head with a dense fine pale pubescence, vertex and upper two-thirds of frons with a dense fine reticulation which has a longitudinal tendency on the frons, against the occiput fine indistinct longitudinal striae are present, lower third of face finely transversely striate above the antennal insertion, longitudinally striate on either side, cheeks striate below, reticulate above. Antennal scape moderately long, its articulate joint long, pedicel one-half longer than its greatest width, funicle joints as wide as the pedicel, 1 almost as long as the pedicel, one-third longer than wide, 2 quadrate, 3 and 4 small and transverse, club 6-jointed, joint 1 small and transverse, 2-5 each twice as wide as long. Scutum and scutellum finely densely pubescent and closely shallowly reticulate-punctate, the sculpture of the scutellum finer than that of the scutum, metanotum rugose. Forewing lightly or distinctly brownish, marginal vein one-third to two-thirds as long as the stigmal, the postmarginal hardly one half longer than the stigmal. Segments 1 and 2 of abdomen strongly striate, 3 finely somewhat irregularly, striate, finely sculptured between the striae which are inclined to fail medially, lateral margins of abdomen pubescent, segments 2 and 3 each with a row of hairs posteriorly, 3 with a few hairs dorsally 4-6 with numerous hairs and minute punctures

Male—Antennae black, the scape yellow (except at apex, pedicel slightly longer than its greatest width, funicle 1 distinctly longer than the pedicel, twice as long as wide, 3 a little shorter than 1, 2 plainly shorter than 1, a little shorter than 3, 4-9 subequal, moniliform, each a little longer than wide

Habitat—Queensland Cooktown, Cairns, Pentland, Rockhampton, Brisbane, Toowoomba, and Chinchilla. New South Wales Moonie River. A small series

Type.—South Australian Museum, I 1363.

A. assimilis Dodd is a true synonym, the wing characters being slightly variable

A single female, labelled "Queensland, A. A. Girault," has the thorax yellowish brown, and probably represents a distinct species

HOPLOTELEIA ASHMEAD

Bull US Nat Museum, vol 45, p 227 (1893)

A world-wide genus containing 30-40 described species, the type, *H floridana* Ashmead, from North America. Ashmead recognised the genus by the "three impressed lines on the mesonotum," and this character has since been generally accepted. However, in most of the Australian species, the median groove of the mesoscutum is not defined, or it may be replaced by a median carina, as in *H orthoptera* Dodd from West Africa, *H serena* Dodd (*Camptoteleia carinata* Krieger) from the Philippine Islands, and the species herein described as *H elevata* Dodd.

The Australian species are very similar in size, colour, and sculpture, and their separation has not been readily accomplished. No reliable specific differences could be found in the wings or antennæ. The characters used to distinguish the species are mostly small, but appear to be valid. The colour of the legs and antennæ seems constant, although as a general rule I do not attach great importance to the colour of the appendages in the *Scelionidæ*.

The nine species recognised in this paper are from Eastern Australia, mostly from coastal or subcoastal districts, *H amica*, and to a lesser degree *H fœderata*, may be inland forms.

Hoploteleia grandis Dodd (Royal Soc. of S. Australia, vol 37, p 176, 1913) is not a member of this genus.

KEY TO THE AUSTRALIAN SPECIES OF *HOPLOTELEIA* ASHMEAD

- | | | |
|---|--|-----------------------------|
| 1 | Mesoscutum with a median carina, occipital margin not uniformly concave | <i>elevata</i> new species. |
| | Mesoscutum without a median carina, occipital margin uniformly concave | 2 |
| 2 | Metanotum with one small tooth, femora black, mesoscutum with a distinct median groove, hind tarsi much longer than their tibiae | <i>atricornis</i> Dodd |
| | Metanotum bidentate, femora red | 3 |
| 3 | Hind tarsi much longer than their tibiae, median groove of scutum rather well marked | <i>persimilis</i> Dodd |
| | Hind tarsi not much longer than their tibiae, median groove of scutum not defined | 4 |
| 4 | Females | 5 |
| | Males | 10 |
| 5 | Apical abdominal segment with a spine on either side | 6 |
| | Apical segment without spines or teeth | 8 |
| 6 | Antennæ almost wholly black, apical spines of abdomen long | <i>australica</i> Dodd |
| | Funicle joints bright red, apical teeth short | 7 |
| 7 | Frontal impression sharply rounded above, coxæ red | <i>sculpturata</i> Dodd |
| | Frontal impression broadly rounded above, coxæ black | <i>amica</i> new species |
| 8 | Antennæ wholly black | <i>gracilicornis</i> Dodd. |
| | Scape and funicle joints red | 9 |

- | | | |
|----|---|------------------------------|
| 9 | Segments 2-5 of abdomen not definitely striate, cheeks largely smooth | <i>pulchricornis</i> Dodd |
| | Segments 2-5 very definitely striate, cheeks densely sculptured | <i>federata</i> new species |
| 10 | Apical spines of abdomen long | <i>australica</i> Dodd. |
| | Apical spines short or absent | 11 |
| 11 | Cheeks largely smooth, coxae red | <i>pulchricornis</i> Dodd |
| | Cheeks densely sculptured | 12 |
| 12 | Coxae black, abdomen much narrower than the thorax | <i>amica</i> new species |
| | Coxae red, abdomen not much narrower than the thorax | <i>federata</i> new species, |

HOPLOTELEIA AUSTRALICA DODD

Royal Soc of S Australia, vol 37, p 133 (1913)

H insularis Dodd, ibidem, p 134

Female —Length, 2 50-3 00 mm

Black tegulae red, coxae black, the legs bright reddish-yellow, antenna black, the scape and funicle joints sometimes suffused with brown

Head from dorsal aspect not more than twice as wide as long, slightly wider than the thorax, from lateral aspect the vertex flat, hardly sloping to the occipital margin, vertex coarsely longitudinally rugose-punctate, frons below the anterior ocellus shallowly reticulate-punctate, along the eye margins from just behind each lateral ocellus to the frontal depression there is fine close scaly reticulation, frontal depression strongly margined, large, longer than wide, sharply convex above, narrowly separated above from the eyes, smooth but showing obscure cross-striae, frons on either side of depression shallowly reticulate-punctate, cheeks coarsely reticulate-punctate, the sculpture shallow toward the mouth, lateral ocelli a little separated from the eyes, distant from the frontal ocellus by less than $1\frac{1}{2}$ times their own diameter, one or two irregular oblique striae connect the frontal and lateral ocelli, head with a sparse pubescence of fine pale hairs. Antennal scape long and slender, the articulate joint very short, pedicel one-half longer than its greatest width, funicle 1 a little longer than the pedicel, twice as long as its greatest width, 2 shorter than 1, 3 a little longer than wide, 4 as wide as long, club slender, not well differentiated, joint 1 wider than long much shorter than 2 which is longest and as long as wide, 3-5 each slightly wider than long. Thorax from dorsal aspect one-fourth longer than its greatest width, from lateral aspect one-third longer than high, pronotum narrowly visible on the sides, strongly rugose-punctate and with long white hairs, scutum three-fourths as long as its greatest width, its anterior margin strongly convex, its surface with scattered hairs, parapsidal furrows deep, punctate, at either end terminating in a large puncture, median lobe of scutum at the median line with confluent punctures which are shallow and indefinite anteriorly and do not form a groove, the rest of the surface and the parapsides faintly wrinkled and with dense fine impressed reticulation, between the posterior ends of the parapsidal furrows are two or three larger

punctures, parapaides with two or three large punctures along anterior margin and a punctate sulcus along lateral margin, scutellum strongly reticulate-punctate, metanotum coarsely foveate, the median process excavated medially and bounded by a straight raised carina, the posterior margin between the ends of these carinae almost straight, the lateral margins oblique, propodeum short, its posterior margin uniformly gently concave, shallowly punctate and pubescent laterally, foveate medially, the lateral carinae short and straight. Posterior tarsi not much longer (8/7) than their tibiae. Forewings reaching apex of abdomen, subhyaline or lightly tinted, venation bright yellow, marginal vein short, not more than one-fourth as long as the stigmal, which is long and slightly oblique, the postmarginal three times as long as the stigmal. Abdomen as long as the head and thorax united, $2\frac{1}{2}$ times as long as its greatest width, segment 1 two-thirds as long as its basal width, 2 one-third longer than 1, 3 one-third longer than 2, a little shorter than 4-6 united, 4 one-half as long as 3, 6 short, transverse, armed on either side with a sharp spine, the blunt apex showing just below, 1 with eight strong complete striae, at base the surface between the striae deeply pitted, posteriorly the surface finely sculptured and with a few fine short striae, 2 rather strongly striate, the striae somewhat irregular, finely sculptured between, laterally with obscure punctures between, 3 more finely and closely striate and with obscure shallow punctures between, punctuation more distinct on 4, the striae faint, 5 for the most part with fine impressed reticulation, but indefinite punctures are present also, 6 densely punctate, lateral margins of abdomen and posterior margin of 2-4 with fine impressed reticulation, abdomen, except basal segment, with a conspicuous pubescence of fine white hairs which are longer laterally and on the apical segments.

Male —Antennae black, the scape and pedicel deep dusky brown, pedicel small, no longer than its greatest width, flagellar joints filiform, 1 almost twice as long as its greatest width, 2 and 3 hardly shorter than 1, 4 plainly shorter than 3 and one-third longer than wide, 4-9 subequal. In structure and sculpture resembling the female.

Habitat —North Queensland Thursday Island, Cairns, Pentland, a series. This species is common in the Cairns district.

Type —South Australian Museum, I 1363

HOPLOTELEIA AUSTRALICA var. *OCCIDENTALIS* DODD

Royal Soc of Queensland, vol 26, p 96 (1914)

Male —Length, 2.65 mm

Differs from the typical form in the colour of the antennae, the scape being bright golden-yellow, the pedicel and basal flagellar joints suffused with yellow.

Females —Unknown

Habitat —North-West Queensland Cloncurry, one male in April. A. P. Dodd.

Type —In the South Australian Museum

HOPLOTELEIA ATRICORNIS DODD

H nigricornis Dodd, Royal Soc of S Australia, vol 37, p 134 (1913),
(preoccupied by *H nigricornis* Cameron, 1912)

H atricornis Dodd, Ent Soc of London, p 341 (1919)

Female—Length, 2.60 mm

Black, tegulae black, coxae black, the femora piceous, the tibiae and tarsi golden-yellow, antennae wholly black

Head from dorsal aspect less than twice as wide as long, vertex hardly sloping to the occipital margin, vertex behind the line of the lateral ocelli strongly longitudinally rugose-punctate, upper frons except medially and around the ocelli with fine dense impressed reticulation, there are about four striae from the anterior ocellus to the frontal impression, frons on either side of the impression shallowly reticulate-punctate, cheeks with fine dense impressed reticulation. Antennae as in *australica*. Thorax a little narrower than the head, one-third longer than its greatest width, pronotum distinctly visible on the sides, very strongly striate, scutum with fine dense impressed reticulation and faint wrinkles, the median lobe with a complete punctate median groove whose margins are carinate, a few weak punctures occur against the posterior margin of the median lobe, scutellum coarsely reticulate-punctate, metanotal plate small, forming an upright triangular tooth, not bidentate, propodeum as in *australica*, the posterior margin uniformly gently concave. Posterior tarsi one-half longer than their tibiae. Forewings lightly stained, marginal vein one-fourth as long as the long stigmal vein, the postmarginal three times as long as the stigmal. Abdomen no longer than the head and thorax united, a little more than twice as long as its greatest width, segment 3 two-thirds longer than 2 as long as 1 and 2 united, a little longer than 4-6 united, 6 on either side with a short sharp spine, 3 densely finely irregularly striate and with shallow indefinite punctures between the striae, 4 and 5 with close fine impressed reticulation, 4 with also very fine striae and traces of shallow punctures.

Male—Length, 2.50 mm

Antennae wholly black, as in *australica*

Habitat—North Queensland Cairns district, one female (type) in December, Herbert River, one pair in March

Type—South Australian Museum, I 1365

Readily distinguished by the dark femora and tegulae, pronounced median groove of the scutum, long tarsi, and the tooth of the metanotum not being bidentate

This species appears identical with a Philippine Island species which is probably *H pacifica* Ashmead. I have before me three females from that locality, one was received from the US National Museum and is labelled *Hoploteleia pacifica* Ash, as identified by Mr A. B. Gahan.

The remaining two were received from Professor C F Baker, of Los Banos, Philippine Islands, and are labelled *Hoploteleia philippinensis* Kieffer, possibly by Kieffer himself, they represent two species, one of which, to judge from Kieffer's description, is correctly determined, the other specimen, which represents the same species as the National Museum example, agrees with the description of *H undens* Kieffer. Thus it would appear that both *undens* Kieff and *atricornis* Dodd are synonyms of *pacificæ* Ashm. However, Ashmead's description of *pacificæ* does not agree with the National Museum example, and although Mr Gahan's determination is probably correct, the doubt that exists justifies the retention of the name *atricornis* for the time being.

HOPLOTELEIA PERSIMILIS DODD

Royal Soc of Queensland, vol 26, p 96 (1914)

H auriscapus Dodd, *ibidem*, p 96

Female—Length, 2.60-3.00 mm

Black, tegulae red, legs golden-yellow, the coxae reddish yellow, antennal scape reddish-yellow, the pedicel and funicle joints suffused with brown, the club black.

Head from dorsal aspect not more than twice as wide as long, from lateral aspect the vertex sloping gently to the occipital margin, vertex and upper frons with fine impressed reticulation and shallow depressions indicating large punctures, posteriorly the vertex is coarsely reticulate or rugose-punctate with a longitudinal tendency, lateral ocelli distant from the anterior ocellus by no more than $1\frac{1}{2}$ times their own diameter and connected with it by one or two oblique striae, a short carina connects the anterior ocellus with the frontal depression which is sharply convex above, frons on either side of the depression reticulate-punctate, but smooth ventrally, cheeks coarsely reticulate punctate and with fine impressed reticulation, and toward the mouth with several strong irregular striae. Antennae as in *australica*. Scutum with fine close impressed reticulation and shallow wrinkles, the median groove represented by a complete row of confluent punctures, and there are a few punctures on either side against the posterior margin, scutellum strongly confluent or reticulate-punctate, posterior margin of metanotal process concave, so that the two carinae project in the form of teeth, propodeum foveate medially, densely punctate and pubescent laterally, its posterior margin uniformly gently concave. Posterior tarsi one-half longer than their tibiae. Forewings lightly stained, marginal vein one-third as long as the long stigmal, the postmarginal three times as long as the stigmal. Abdomen slightly longer than the head and thorax united, almost three times as long as its greatest width, segment 3 two thirds longer than 2, as long as 1 and 2 or 4-6 united, spines on either side of 6 short and acute, sculpture as in *australica*, except that the punctures between the striae on segment 3 are more distinct, pubescence as in *australica*.

Male.—Coxæ dark, at least at base, spines at apex of abdomen long and slender. Antennal scape red, dusky toward apex, the pedicel dusky, the flagellum black, segmentation as in *australica*.

Habitat—North Queensland Herbert River (type), Innisfail. Cairns, four females, two males.

Type—South Australian Museum, I 11009

The sexes were originally described as distinct species. At once differing from *australica* in the long posterior tarsi. The median punctures of the scutum are more in the form of a groove than in *australica*, the apical spines of the abdomen are shorter in the female, the concave posterior margin of the metanotal process gives a more apparent bidentate effect, and segment 3 of the abdomen is relatively longer.

HOPLOTELEIA GRACILICORNIS DODD

Royal Soc. of Queensland, vol 26, p 97 (1914)

Female—Length, 2.75–3.25 mm

Black, the tegulae red, legs, including the coxæ, bright reddish-yellow, antennæ wholly black.

Head from dorsal aspect twice as wide as long, the vertex hardly sloping to the occiput, behind the ocelli the vertex is very strongly reticulate- or rugose-punctate with a longitudinal tendency, between the ocelli are three or four striae or rugae, upper frons shallowly reticulate-punctate medially, with fine impressed reticulation laterally, cheeks coarsely reticulate-punctate and with fine reticulation also, antennal impression narrowly rounded above. Antennæ as in *australica*. Thorax scarcely as wide as the head, one-fourth longer than its greatest width, scutum with fine close impressed reticulation and shallow wrinkles or depressions suggesting punctures, the median lobe with large confluent punctures toward posterior margin, along the median line, and against the anterior margin, scutellum with large confluent punctures, metanotal plate faintly bidentate, the carinae forming the teeth close together, posterior margin of propodeum faintly concave with a slight projection at the junction of the lateral carinae. Forewings reaching apex of abdomen, subhyaline, venation bright yellow, marginal vein one-fourth as long as the stigmal, the postmarginal $2\frac{1}{2}$ times as long as the stigmal. Posterior tarsi scarcely longer than their tibiae, posterior femora not much swollen. Abdomen no longer than the head and thorax united, hardly more than twice as long as its greatest width; segment 3 one third longer than 2, as long as 4-6 united, somewhat shorter than 1 and 2 united, 6 before apex faintly truncate, without a spine or tooth on either side, 2 strongly irregularly striate, sculptured between the striae but without definite punctures, 3 with large shallow punctures and fine indefinite striae, 4 with similar but finer sculpture, 5 with fine impressed reticulation and numerous shallow punctures, 6 with fine reticulation.

Male — Unknown

Habitat — New South Wales Glen Innes, A M Lea (type)
Queensland Mount Tambourine and Cairns, A P Dodd Three females

Type — In the collection of the Government Entomologist of New South Wales

Differs from *sculpturata* in the less swollen hind femora, colour of antennæ, absence of spines at apex of abdomen, and less noticeable punctuation of segment 2 of abdomen, from *australica* in the colour of the coxæ, absence of spines at apex of abdomen, more definite punctuation and less definite striation of segment 3 of abdomen

HOPLOTFLEIA SCULPTURATA Dodd

Royal Soc of Queensland, vol 26, p 95 (1914)

Female — Length, 3.75 mm

Black, the tegulæ red, legs, including the coxæ, bright reddish-yellow, first three funicle joints clear reddish-yellow, the scape and pedicel dusky red or almost black

Head from dorsal aspect about $2\frac{1}{2}$ times as wide as long, the vertex flat, not sloping to the occipital margin, vertex behind the line of the lateral ocelli very strongly reticulate- or rugose-punctate with a longitudinal tendency, upper frons with shallow depressions and close fine impressed reticulation, between the ocelli and on the upper frons are a few irregular striae or rugæ, cheeks coarsely reticulate punctate except for a small smooth area ventrally, frontal impression very sharply rounded above, smooth, without definite striae. Antennæ as in *australica*. Thorax about one-fourth longer than its greatest width, scarcely as wide as the head, scutum with fine close impressed reticulation and shallow wrinkles or depressions suggesting punctures the median lobe broadly confluent punctate posteriorly, this sculpture continued forward narrowly for its entire length but not forming a groove, against the anterior margin are close punctures scutellum strongly reticulate-punctate, metanotal plate large, obtuse and faintly bidentate posteriorly, the two carinæ or teeth close together, posterior margin of propodeum almost straight, with a short blunt projection at the junction of the lateral carina. Posterior tarsi slightly longer than their tibiae (7.6), posterior femora considerably swollen. Forewings reaching apex of abdomen, marginal vein one-fourth as long as the long stigmal, the postmarginal $2\frac{1}{2}$ times as long as the stigmal. Abdomen no longer than the head and thorax united, twice as long as its greatest width, segment 3 two-thirds longer than 2, a little shorter than 1 and 2 united, as long as 4-6 united, 6 with an apical truncate carina armed at either side with a short spine or tooth, 2 strongly sparsely striate, medially with large shallow punctures between the striae laterally the punctures are coarse and distinct, 3 with large shallow confluent punctures and with

fine irregular indefinite striæ, 4 with fine punctures, the striæ hardly discernible, 5 with fine impressed reticulation and numerous punctures, 6 rugose-punctate

Male—Unknown

Habitat—New South Wales Tweed River, one female (type) in May, A P Dodd North Queensland Dunk Island, one female in August, H Hacker

Type—South Australian Museum, I 11007.

The punctuation of segments 2 and 3 of the abdomen is much stronger than in *australica*. The posterior femora are more noticeably swollen than in any of the known Australian species

HOPLOTELEIA ELEVATA NEW SPECIES

Female—Length, 3.20 mm

Black, the tegulae red, legs, including the coxæ, bright reddish-yellow, antennal scape red, the pedicel dusky, the funicle joints faintly suffused with red

Head from dorsal aspect not more than twice as wide as long, the vertex not descending to the occiput, slightly wider than the thorax; occipital margin not uniformly concave, broadly straight or truncate medially and angled laterally, highly polished, behind the ocelli to the occiput are strong sparse irregular longitudinal rugæ or striæ, between which are large shallow indefinite punctures, between the ocelli is a very large triangular puncture, upper frons with shallow indefinite reticulate punctures, on either side of the anterior ocellus and narrowly behind the lateral ocelli is fine impressed reticulation, cheeks with longitudinal rows of confluent punctures, frontal impression acutely rounded above. Antennæ slender, funicle 1 one-half longer than the pedicel three times as long as its greatest width, 3 very distinctly longer than wide, 4 as long as wide, club 1 somewhat wider than long, 2 a little longer than wide, 3, 5 each as wide as long. Thorax from dorsal aspect one-third longer than its greatest width, from lateral aspect one-half longer than high, median lobe of scutum with a complete median carina, on either side strongly transversely rugose or irregularly striate, the lateral lobes shallowly reticulate-punctate, narrowly on either side of the parapsidal furrows is fine impressed reticulation, scutellum coarsely reticulate-punctate, posterior margin of metanotal plate concave and bidentate, the median carina well apart and a little divergent, posterior margin of propodeum definitely concave, the blunt projections well marked. Posterior femora somewhat swollen, posterior tarsi slightly longer than their tibiae. Forewings slightly infusate, marginal vein one-third as long as the stigmal, the postmarginal slightly more than twice as long as the stigmal. Abdomen no longer than the head and thorax united, $2\frac{1}{2}$ times as long as its greatest width, segment 3 two-thirds longer than 2, almost as long as 1 and 2 united, 6 on either side with a stout spine, 2 strongly striate, between the striæ almost

smooth, 3 finely densely irregularly striate and densely punctate, the punctures of moderate size or very small, 4 with fine striæ and dense fine punctures, the median line and posterior margin with fine reticulation, 5 with fine impressed reticulation and scattered punctures, 6 with fine reticulation

Male—Antennæ black, the scape red, the pedicel dusky, funicle 2 as long as 1 or 3 Segments 4-6 of abdomen with fine reticulation and scattered punctures which are more numerous on 4, apical spines longer than in the female

Habitat—North Queensland Cairns and Innisfail, one female, two males, in November and December, A P Dodd

Holotype and *Allotype* in the Queensland Museum

Paratype in the author's collection

At once distinguished by the median carina and transverse rugæ of the median lobe of the mesoscutum, and the shape of the occipital margin

HOPLOTELEIA PULCHRICORNIS DODD

Royal Soc of S Australia, vol 37, p 134 (1913)

H acuminata Dodd, *ibidem*, p 177

Female—Length, 3.25 mm

Black, tegulæ red, legs, including the coxæ, and first six antennal joints bright golden- or reddish-yellow

Head from dorsal aspect a little more than $2\frac{1}{2}$ times as wide as long, no wider than the thorax, vertex sloping rather sharply to the occipital margin, vertex behind the ocelli strongly reticulate-punctate, toward the occiput longitudinally rugose punctate, between the ocelli are several connecting striæ, upper frons medially shallowly reticulate punctate, on either side with fine impressed reticulation, cheeks very narrow above, the ventral half for the most part smooth with a few punctures and obscure grooves, frontal impression rather broadly rounded above, without definite cross-striæ, but with oblique striæ laterally Antennæ as in *australica* Thorax one fifth longer than its greatest width, scutum with shallow depressions or obscure punctures and close fine impressed reticulation, against the posterior margin of the median lobe with large confluent punctures, with smaller less distinct punctures against its anterior margin, and obscure punctures along the median line, parapsidal furrows separated posteriorly by one-half their length, scutellum strongly confluent punctate, metanotal process bluntly bidentate, the teeth well-separated, the posterior margin concave, the median carinæ diverging from base, posterior margin of propodeum slightly concave, faintly projecting at the junction of the lateral carinæ, metapleura strongly striate in centre Posterior femora not much swollen, posterior tarsi no longer than their tibiae Forewings subhyaline or faintly yellowish, venation bright yellow, marginal vein

one-fourth as long as the long stigmal vein, the postmarginal $2\frac{1}{2}$ times as long as the stigmal. Abdomen a little (about one-sixth) longer than the head and thorax united, two and one-third times as long as its greatest width, segment 3 about one-fourth longer than 2, three-fourths as long as 1 and 2 united, 6 as long as 5, without a truncate plate or spines, pointed at apex, 2 with rather distinct punctures between the striae, the punctures very distinct laterally, 3 confluent punctate and with fine indistinct or indefinite striae, 4 with similar finer sculpture but medially with fine impressed reticulation and scattered punctures, 5 with fine impressed reticulation and numerous punctures, 6 with fine reticulation and fine indefinite punctures.

Male—Antennal scape yellow, the pedicel brownish yellow, the basal flagellar joints suffused with yellow.

Habitat—Queensland Cairns district (type), Bowen, Biggenden, Blackall Range, Brisbane, Mount Tambourine, a small series.

Type—South Australian Museum, I 1366.

In this species the head is more transverse than usual and descends noticeably to the occiput. The absence of apical teeth on the abdomen is found in *gracilicornis* and *fæderata*, in the former the antennæ are wholly black, while the distinguishing characters of *fæderata* are given later.

The sexes were originally described as distinct species. This species is parasitic on the eggs of a large *Tettigonid* (*Orthoptera*).

HOPLOTELEIA FÆDERATA NEW SPECIES

Female—Length, 3–3.50 mm.

Black, tegulae red, legs, including the coxae, bright reddish-yellow, antennal scape and first three funicle joints bright reddish-yellow, the pedicel fuscous.

Head from dorsal aspect a little wider than the thorax, a little more than twice as wide as long, the vertex not descending to the occiput, vertex strongly reticulate-punctate without a longitudinal tendency, behind each lateral ocellus and laterally on the upper frons with close fine impressed reticulation, between the ocelli are two or three connecting striae, upper frons reticulate-punctate, frontal impression very broadly rounded above, more or less transversely striate, cheeks very strongly reticulate- or rugose punctate. Antennæ normal. Thorax a little longer than its greatest width, scutum with fine close impressed reticulation and shallow depressions or obscure punctures, with large confluent punctures posteriorly on the median lobe, and smaller punctures against the anterior margin of the median lobe, scutellum with large confluent punctures, metanotal plate concave and bluntly bidentate at apex, the median carinae diverging from base, posterior margin of propodeum faintly concave, with a blunt projection at the lateral carina. Legs spiny, posterior femora somewhat swollen, posterior tarsi no longer

than their tibiæ or a little shorter. Forewings reaching apex of abdomen, subhyaline or faintly yellowish, marginal vein one-third as long as the stigmal, the postmarginal three times as long as the stigmal. Abdomen a little (about one-sixth) longer than the head and thorax united, two and one-third times as long as its greatest width. Segment 3 plainly shorter than 1 and 2 united, one-fourth longer than 2, 6 about as long as 5, acuminate, without apical teeth. 2 very strongly striate, hardly sculptured between the striæ medially, with obscure punctures laterally, 3 quite strongly striate, with shallow punctures between, 4 and 5 with finer striæ, which are still dense and distinct, the punctures more definite on 5, the median line narrowly smooth except for a few punctures, 6 with numerous punctures and fine impressed reticulation.

Male — Antennal scape red, the basal funicle joints and the pedicel a little suffused with red. Abdomen not much narrower than the thorax (5.4), 2½ times as long as its greatest width, the punctuation of segments 3-5 more distinct than in the female, apical segment gently concave at apex and with a small obtuse tooth on either side.

Habitat — Queensland. Chinchilla, twelve females, eleven males, January-March, A. P. Dodd, Westwood, one pair in March, A. P. Dodd.

Holotype and *Allotype* in the Queensland Museum.

Paratypes in the author's collection.

Very closely related to *pulchricornis* from which it may be distinguished by the densely sculptured cheeks, very definite striæ of segments 3-5 of abdomen, more spiny legs, and somewhat swollen hind femora. In *sculpturata* the scape is darker than the funicle joints, the metanotum is less evidently bidentate, the female abdomen is bispinose at apex, and the hind femora are much swollen. In *amica* the coxæ are black, the shallow punctures of the mesoscutum are hardly discernible, the posterior margin of the propodeum is more concave with the projections more definite, the female abdomen is bispinose at apex, and the male abdomen is more slender.

HOPLOTELEIA AMICA NEW SPECIES

Female — Length, 3.25-3.50 mm.

Black, the tegulæ red, legs bright reddish-yellow, the coxæ black, the tarsi dusky, first five antennal joints reddish-yellow, the pedicel sometimes dusky.

Head from dorsal aspect a little more than twice as wide as long, a little yet distinctly wider than the thorax, vertex hardly descending to the occiput, vertex and upper frons coarsely reticulate-punctate without a longitudinal tendency, between the ocelli are about two connecting striæ, behind the lateral ocelli and on either side of the upper frons is fine impressed reticulation, frontal impression very broadly rounded above, shining, without definite striæ, cheeks coarsely reticulate-punctate. Antennæ normal. Thorax a little longer than its

greatest width, scutum with fine close impressed reticulation and finely wrinkled, the median lobe with large confluent punctures posteriorly and smaller confluent punctures against the anterior margin, scutellum coarsely confluent punctate, metanotal plate deeply concave and plainly bidentate posteriorly, the median carinae wide apart and parallel, posterior margin of the propodeum distinctly concave medially, with a strong blunt projection at the junction of the lateral carinae. Posterior femora a little swollen, posterior tarsi slightly longer (6.5) than their tibiae. Forewings reaching apex of abdomen, subhyaline, venation fuscous, marginal vein one-third as long as the stigmal, the postmarginal almost three times as long as the stigmal. Abdomen no longer than the head and thorax united, slightly more than twice (2.9) as long as its greatest width, segment 3 two-thirds longer than 2, almost as long as 1 and 2 united, 6 before the apex truncate and armed on either side with a short sharp spine, 2 strongly striate, hardly sculptured between the striae except laterally, 3 densely rather finely irregularly striate and with shallow obscure punctures between, 4 with similar finer sculpture, the punctures more distinct on 5. 6 reticulate punctate.

Vale - Antennae black, the scape and the pedicel suffused with red. Abdomen distinctly narrower (2.3) than the thorax, two and two-thirds as long as its greatest width, apical segment broadly truncate and with a short tooth on either side.

Habitat - South Queensland. Chinchilla 14 females, 1 male January-March, A. P. Dodd, Goondiwindi three females, two males in January, A. P. D. New South Wales. Warialda one female in January.

Holotype and *Allotype* in the Queensland Museum.

Paratypes in the author's collection.

The shallow depressions or obscure punctures of the scutum are much less evident than in *sculpturata pulchricornis*, and *federata*, while the projections of the posterior margin of the propodeum are more pronounced. Differs from the female of *federata* in the smooth frontal impression, black coxae, and the presence of the short apical spines on the abdomen, from *sculpturata* in the normal hind femora, black coxae, and broadly rounded frontal impression, from *pulchricornis* in the black coxae, apical spines of abdomen, and densely sculptured cheeks.

The Location of Saponin in the Foam-bark Tree (*Jagera pseudorhus*).

By W. D. FRANCIS, Assistant Government Botanist

Plates I and II

(Read before the Royal Society of Queensland, 25th June, 1928.)

- I Introduction
- II Methods
- III The location of saponin in the stem and branchlets
- IV The location of saponin in the root
- V The location of saponin in the walls of the fruit
- VI The location of saponin in the leaflets
- VII The location of saponin in the young twigs
- VIII Interpretation of results
- IX The function of saponin in the species
- X Summary

I—INTRODUCTION

The bark of *Jagera pseudorhus* was a commercial commodity in Australia during the war. It was used as a substitute for quillaja bark, which produces a "head" or foam on cordials. The utilisation of the local product was due in a great measure to the enterprise of the Forestry authorities of Queensland, who at the time constituted a section of the Department of Public Lands. Mr. C. J. Trist, the Secretary of the present Provisional Forestry Board of Queensland, informed the writer that about 9 tons of the bark of the species were collected and disposed of to brewers and cordial manufacturers. Owing to the scattered distribution of the trees which increased the cost of collection, the demand for the bark has discontinued in recent years. In a report [12] published in 1919, Mr. E. H. F. Swain, then Director of Forests, states that a sample of the bark of *Jagera pseudorhus*, which was submitted to the Government Analyst, was found to contain 6.9 per cent of saponin.

R. Hamlyn-Harris and F. B. Smith [7] investigated the poisonous action on fish of infusions of the bark, which was known to be used by the aborigines in procuring fish for food. Hamlyn-Harris and Smith found that the bark contained saponin, and is a rapid and powerful piscicide, producing death in concentration of 1/1000. They also ascertained that frothing of an infusion of the bark took place at a dilution of 1/10000, and hæmolysis of blood corpuscles at a concentration of 1/14000. The leaves were found by them to be free of saponin. The toxic effect on fish and the hæmolytic property of the saponin as demonstrated by these authors indicate that the use of the bark in the manufacture of cordials may not be advisable.

The foam-bark tree is more familiarly known in a technical sense under A. Richard's name of *Cupania pseudorhus*. The species was transferred to the genus *Jagera* by L. Radlkofer, who applied himself to

the study and revision of the Sapindaceæ. As Radlkofer's nomenclature appears to be accepted by very many systematists, his combination *Jagera pseudorhus* is adopted in this paper. It is regrettable that the name which is more familiar locally has in consequence to be regarded as a synonym.

In habit of growth the foam-bark tree is not a large species. It is a rain-forest tree. So far as the writer has observed it in subtropical rain forests, it does not exceed about 60 feet in height and 12 inches in stem diameter. When growing in the open the trees produce a dome-shaped head of foliage and a short stem. Generally the species is sparsely distributed. F. M. Bailey [1] states that it ranges in Queensland from the Brisbane River to the Barron River Ranges of North Queensland. According to Bentham [2] it occurs as far south as the Hastings River in New South Wales. These locality records show that it ranges from 17 deg S to 32 deg S. It is not found far inland from the coast and coastal ranges. It is confined to Australia.

The properties of saponins and their distribution in the plant kingdom are outlined by Greshoff [5], Kobert [8], Haas and Hill [6], Molisch [10], and Czapek [4]. J. H. Maiden [9] has also published some notes on saponins and their occurrence in Australian plants. It is observed by Kobert that such a wide distribution in the plant kingdom as that of saponins is possessed only by the essential oils. Kobert and Haas and Hill state that all saponins when treated with strong sulphuric acid exhibit red or violet colours. According to the authors quoted above, the saponins may be briefly described as nitrogen-free glucosides which on hydrolysis yield sugars such as glucose, galactose, arabinose, and rhamnose, together with other substances termed sapogenins whose constitution is unknown, they are amorphous and colloidal.

Molisch [10, p. 196] quotes Greshoff to the effect that saponins in barks and in the rind of fruits act as protective substances, and in seeds and roots serve as reserve materials. Molisch also points out that the location of saponins is not known in most plants, and that it is therefore desirable that someone should investigate microchemically their occurrence in the cells and tissues of the numerous unstudied plants.

F. Czapek [4] includes the saponins under the chapter heading of little known, omniscularly distributed, nitrogen-free end-products of plant metabolism. He states [4, p. 527] that, according to the microchemical investigations of Rosoll and Hanausek, saponin occurs in solution in the cell sap, principally in the parenchyma cells of bark, wood and medullary rays. Further on [4, p. 535] he remarks that different saponin bodies probably occur in the Sapindaceæ.

II—METHODS

In locating saponin in various parts of the plant four properties of saponin were utilised. (1) the production by shaking of a foam on the surface of the solution obtained by steeping saponin-containing tissues in distilled water, (2) the production of a reddish-violet colour on treatment of sections with equal parts of concentrated sulphuric acid

and absolute alcohol, (3) the insolubility of almost all saponins in absolute alcohol, (4) the solubility of most saponins in water. The treatment with concentrated sulphuric acid and absolute alcohol is a modification of a method adopted by Hanausek and outlined by Molisch [10, p 196]. In addition to the application of sulphuric acid and alcohol Hanausek finally added ferric chloride, which in the presence of saponins turned the reddish-violet colour to brown or brownish blue. The writer was unable to obtain this final colour reaction with ferric chloride either in the saponin-containing sections or in the solutions of saponin contained in test tubes.

This colour test with ferric chloride is apparently not universally applicable to saponins, as Haas and Hill [6, p 165] state that concentrated sulphuric acid containing a little ferric chloride gives with many saponins a blue or bluish-green colour or fluorescence. The application of concentrated sulphuric acid alone to sections of the tissues was not found satisfactory. The action of the concentrated acid partly destroyed the tissues on account of its solvent action on cellulose. It also converted the greater part of the sections to a reddish-brown colour and produced numerous gas inclusions which made observation of the tissues difficult.

The addition to the concentrated acid of an equal volume of absolute alcohol as used by Hanausek produced a very useful testing combination which gave good results. Sections of those tissues which showed positive reactions with the concentrated sulphuric acid and alcohol were also submitted to a solubility test by heating them in distilled water, and another series of sections of the same tissues was subjected to an insolubility test by treatment with absolute alcohol. The sections were then tested with the sulphuric acid-alcohol combination. If they gave positive reactions in the cases in which they were treated with absolute alcohol and negative reactions in the instances in which they were heated in water, the results were regarded as confirmatory.

III—THE LOCATION OF SAPONIN IN THE STEM AND BRANCHLETS

Small pieces of the fresh bark of the stem of a large tree which were steeped in distilled water produced abundant frothing when shaken. The froth was immediately dispersed by the addition to the liquid of a few drops of alcohol. The dispersive effect of alcohol and ether on saponin froth is mentioned in the British Pharmaceutical Codex [3]. Sections of the bark of the stem on treatment with the sulphuric acid-alcohol combination developed the reddish-violet colour in the walls of many of the sclerenchyma cells and in the walls of many of the bast fibres and parenchyma cells in the outer part of the phloem.

There is a continuous but often very uneven ring of sclerenchyma in the bark of *Jagera pseudorhus*. It is situated between the cortex and phloem (see Plate I, Figs 1 and 2). Sclerenchyma either connected with or isolated from the continuous ring is often developed in the cortex and in the outer part of the phloem. Radlkofel [11] remarks that the ring of sclerenchyma is characteristic of the bark of nearly all of the genera of Sapindaceae. Sections of the bark of the stem when heated in distilled water for one hour and treated with the sulphuric acid-alcohol

combination showed no reddish-violet colouration. On the other hand sections of the same tissues placed in absolute alcohol for one hour and treated with the reagent gave a positive colour reaction in the walls of many of the cells of the tissues which gave the positive reaction in the original sections which were not treated with absolute alcohol. It is therefore assumed that saponin is present in the walls of many of the sclerenchyma cells and in the walls of many of the bast fibres and parenchyma cells of the outer phloem.

Owing to the presence of a large amount of sclerenchyma in the bark of the stem, very thin sections of it could not be cut with ease. For this reason observations on the distribution of saponin in the bark of the stem were not so precise as those made upon sections of branchlets. No fresh wood of the stem was available for investigation.

Branchlets about 9 mm. in diameter were selected for study. Before commencing microscopical work it was ascertained that small pieces of the bark and wood, after being placed in distilled water, produced a foam on the surface of the liquid when it was shaken. The froth was more abundant in the solutions obtained from the bark. Sections of the branchlets, upon treatment with the sulphuric acid-alcohol combination showed the reddish-violet colouration in the walls of many of the cells of the cortex, in the walls of some of the cells of the sclerenchyma, and in the walls of many of the bast fibres and parenchyma cells of the outer phloem. The cells of the periderm did not show the colour reaction. In some sections the most intense colour was developed in the immediate vicinity of large sclerenchyma cells. These sclerenchyma cells were surrounded by the reddish-violet colour and were situated on the inner side of the sclerenchyma ring. The wood of the branchlets gave faint reactions which were confined to the very young wood. The walls of some of the wood rays, of some of the wood fibres, and of some of the vessels showed a faint reddish-violet colour.

Both the wood and bark of branchlets gave negative reactions after being heated in distilled water for one hour, and positive reactions after treatment with absolute alcohol. Sections which had remained in absolute alcohol for several days showed the colour reaction with the sulphuric acid-alcohol in the same tissues which gave positive results with fresh material. The sclerenchyma ring in the bark of the branchlet measuring 9 mm. in diameter was very irregular and its maximum breadth was 48 mm. The structure of the outer part of the bark of the branchlets is shown in Figs 1, 2, and 3, Plates I and II.

IV—THE LOCATION OF SAPONIN IN THE ROOT

The material for investigation was taken from a large tree, and consisted of a secondary root 5 mm. in diameter. Small pieces of the bark and wood produced abundant frothing on shaking the distilled water in which they were steeped. As in the stem, a ring or sheath of sclerenchyma occurs between the cortex and phloem. The application of the sulphuric acid-alcohol combination to sections showed that saponin in the secondary root is distributed in a similar manner to that in the branchlets. The cortex, outer part of the phloem, and the very

young wood gave positive reactions, and the reddish-violet colour was principally located in the cell walls. As in the branchlets, saponin was not uniformly distributed but occurred in many of the cells of the tissues.

The young wood of the root reacted much more strongly than that of the branchlets, and an intense reddish-violet colour developed in two or three rows of the wood fibres nearest to the cambium. The bast fibres and parenchyma were the parts of the outer phloem most affected by the testing solution. The sections treated with absolute alcohol and those heated in distilled water gave positive and negative reactions respectively when subjected to the action of the sulphuric acid-alcohol combination. The periderm yielded no indication of the presence in it of saponin. The structure of the outer part of the secondary root is shown in Fig. 4, Plate II.

V — THE LOCATION OF SAPONIN IN THE WALLS OF THE FRUIT

The fruit is three-lobed and three-celled. Externally it is covered by dense, brown rigid hairs or setae. The walls of the fruit are very thick and hard. They are bounded externally and internally by a coating of parenchymatous tissue in which groups of sclerenchyma are embedded. The part surrounded by the external and internal coatings is composed of loose-celled tissue. Numerous vascular bundles passing from the internal coating to the external one traverse the loose-celled tissue. The walls of immature fresh fruit were examined. Small pieces immersed in distilled water and shaken produced on the surface of the solution an abundant froth which was immediately dispersed by a few drops of alcohol. Transverse sections of the walls when treated with the sulphuric acid-alcohol combination showed the reddish-violet colour in the walls of many of the cells of the sclerenchyma groups and in many of the spiral vessels of the vascular bundles. Some of the cells in each instance remained uncoloured.

The sections treated with absolute alcohol for one hour and subjected to the sulphuric acid-alcohol combination gave results similar to those of the original sections which were not treated with absolute alcohol. The sections heated in water for one hour when placed in the testing reagent developed a very faint reddish-violet colour in some of the spiral vessels of the vascular bundles but the sclerenchyma cells remained unaffected. Evidently the saponin was not thoroughly extracted from some of the spiral vessels by the treatment with water. Unfortunately no seeds were available for examination. In the fruits collected the ovules remained rudimentary.

VI — THE LOCATION OF SAPONIN IN THE LEAVELS

The observations outlined in this section were made before the writer was aware of Hamlyn-Harris and Smith's statement [7] that they had found the leaves of the species to be free of saponin. Sections cut in a transverse direction to the midrib of the leaflet, when treated with the sulphuric acid-alcohol combination, developed the reddish-violet colour in the cells of the xylem of the vascular bundles composing the internal part of the midrib, in a few of the cells composing the sheath

of sclerenchyma surrounding the vascular bundles of the midrib, and in many of the cells surrounding the sclerenchyma sheath. The colour reaction was also observed in the spiral vessels of some of the vascular bundles composing the smaller veins of the leaflets. Although some of the colour was present in the interior of the cells, the greater part was concentrated in the cell walls. The remaining tissues of the leaflet gave negative results with the reagent.

Sections placed in absolute alcohol for one hour reacted in the same way as the original ones. Some sections which were stored in absolute alcohol for two days also showed the colour reaction in a similar manner when treated with the sulphuric acid-alcohol combination. The sections heated in water for one hour, however, retained some of their property to produce with the reagent the reddish-violet colour, which in this instance was decidedly fainter than that of untreated sections. It is therefore evident that the substance producing the reddish-violet colour with the reagent is only partly extracted by heating in water for one hour. The midribs of six leaflets were dissected out, cut into small pieces, and placed in distilled water for one hour. The solution when shaken produced a small amount of froth which was dispersed by the addition of a few drops of alcohol.

VII—THE LOCATION OF SAPONIN IN THE YOUNG TWIGS

In order to test the validity of some ideas which were suggested by the distribution of saponin in other parts of the plant, it was decided to ascertain its location in the very young twigs. For this purpose young twigs were sectioned at positions from 6 to 9 mm below the growing point. Sections when placed in distilled water for 30 minutes produced a froth which was immediately dispersed by a few drops of alcohol. Sections treated with the sulphuric acid-alcohol combination developed the reddish-violet colouration in a few of the cells of the cortex, in the cells composing the sclerenchyma groups situated in the cortex near the projecting angles of the twig, in all of the cells composing the sclerenchyma ring, in all of the cells composing the xylem groups, and in many of the lignified cells of the medulla. It was observed that the colour was less in evidence in the cells of the cortex of these sections than in those of the branchlets. The reddish-violet colour was mostly concentrated in the cell walls, but it was also present in the small lumina of many of the sclerenchyma cells.

The sections treated with absolute alcohol for one hour and then placed in the reagent gave results similar to those obtained by placing sections direct in the reagent. The sections heated in distilled water for one hour and then placed in the reagent showed a faint reddish-violet colour in a few of the cells of some of the xylem groups, otherwise the tissues gave negative results. The xylem groups in which the faint reddish-violet colour was formed after heating the sections in water constituted a very small proportion of the number which gave positive results in the sections placed directly in the sulphuric acid-alcohol combination.

The sclerenchyma ring in the bark of the young twigs which were sectioned was much more regular than that of the branchlets. It measured 04 to 06 mm in breadth.

VIII—INTERPRETATION OF RESULTS

The results obtained from the sections of the leaflets were not so definite as those produced by the other parts examined. The saponin-like substance in the midrib of the leaflets is evidently less soluble in water than the saponin demonstrated in other parts of the tree. According to Kobert [8, p. 244] a few saponins are only soluble in water to which a few drops of alkali have been added. The saponin-like substance in the midrib of the leaflets may not be entirely different from saponin in the other parts, as its location corresponds with that of saponin in some of the other tissues. For instance, it occurs in tissue adjacent to a sclerenchyma sheath and is sometimes located in the cells of the sclerenchyma sheath. In this respect its location is comparable to that of saponin in the cortex and sclerenchyma sheath of the branchlets and in the cortex of the roots. It also occurs in the cell walls of the xylem of the vascular bundles of the midrib, and in this instance similar in location to saponin in the xylem groups of the young twigs and in the xylem of the roots. The absence of saponin from almost the whole of the chlorophyllous tissue of the leaflets was indicated by the investigations. This observation is partly confirmed by Hamlyn-Harris and Smith [7], who found the leaves to be free of saponin. It suggests that saponin in this species is not a direct product of photosynthesis.

In some of the tissues saponin was not uniformly distributed. It was found to occur irregularly in the cortex and outer phloem of the branchlets and roots. In the xylem groups and sclerenchyma sheath of the young twigs it was evenly distributed. The saponin (?) in the xylem of the vascular bundles of the midrib of the leaflets was also generally and evenly distributed. In all of the tissues examined the greatest concentration of saponin was found in the cell walls.

The possible connection of saponin with the formation of the cell walls of the sclerenchyma and xylem was suggested to the writer by the position of saponin in the sections of the stem, branchlets, roots, and walls of the fruit. Saponin was often concentrated in the cell walls of sclerenchyma. Examples were provided in the case of the sections of the walls of the fruit and of the bark of the stem and branchlets. In the root the walls of the very young wood fibres showed an intense reaction for saponin, and the presence of a slight amount of saponin was indicated in the walls of the cells of the very young wood of the branchlets. To test the validity of the hypothesis associating saponin with cell-wall formation, it was decided to ascertain the location of saponin in the very young twigs. If saponin is connected with the construction of the walls of the cells of the sclerenchyma and xylem, it could be anticipated that saponin would be concentrated in the walls of these kinds of tissue in the young twigs, because sclerenchyma and xylem are being formed or are only recently formed in this part of the plant. The result of the

investigation of the young twigs supported the hypothesis in a positive way. The entire sclerenchyma sheath, the sclerenchyma groups in the cortex near the angles of the twigs, and all of the cells of the xylem groups showed an intense reaction for saponin, and the colour reaction was most strongly developed in the cell walls.

The presence of saponin in the bast fibres and parenchyma of the outer part of the phloem of the branchlets could be explained by the fact that these tissue elements are the ones which are transformed into sclerenchyma as growth proceeds. In the cortex of the branchlets saponin is also abundant in many of the cells. Although it would be difficult to show that the actual cortical cells which contain saponin are in course of conversion into sclerenchyma, there exists in the cortex of the branchlets a large amount of sclerenchyma either in groups or in the form of isolated cells.

A very large amount of sclerenchyma is formed in the outer portion of the bark of the branchlets. This is shown by the fact that the sclerenchyma sheath in the young twigs measured only 0.4 to 0.6 mm in thickness while in the branchlets measuring 9 mm in diameter the sheath of sclerenchyma attained a maximum breadth of 4.8 mm. The photomicrograph of the transverse section of the branchlet which is reproduced in Fig. 1 shows the great extent of the sclerenchyma and the irregular thickness of the sheath which it forms.

IX—THE FUNCTION OF SAPONIN IN THE SPECIES

The fact that saponin was found in greatest concentration in the cell walls suggests that its function is concerned with the construction or composition of the cell walls. The presence of saponin in, or its association particularly with, the cell walls of sclerenchyma and xylem (wood) appears to connect it with the development of these kinds of tissue. The association of saponin with the structure or composition of cell walls, which are composed of either cellulose or wood, is partly supported by the facts that saponins contain carbohydrates and that cellulose is a complex carbohydrate which also enters in large proportions into the composition of wood. The investigations have not shown where saponin originates in the species. It is evidently absent from almost the whole of the chlorophyllous tissue of the leaflets. Possibly it arises in the protoplasm and is transferred in very dilute solution from cell to cell through the perforations of the cell walls.

X—SUMMARY

Saponin was found to be located in the following parts of the tree — Many of the cells of the cortex of the stem, branchlets, and secondary roots, some of the cells of the sclerenchyma sheath of the stem, branchlets, and secondary roots, all of the cells of the sclerenchyma sheath of the young twigs, many of the bast fibres and parenchyma cells of the outer part of the phloem of the stem, branchlets, and secondary roots, all of the cells of the xylem groups of the young twigs, the very young wood fibres of the secondary root, many of the cells of the sclerenchyma groups in the walls of the fruit, and many

of the spiral vessels of the vascular bundles in the walls of the fruit. Faint reactions for saponin were shown by the various tissue elements of the very young wood of the branchlets. The greatest concentration of saponin was found in the cell walls of the various tissues. Almost the whole of the chlorophyllous tissue of the leaflets gave negative reactions with the testing reagent (concentrated sulphuric acid and absolute alcohol in equal parts by volume). A saponin-like substance was located in the cell walls of the xylem of the vascular bundles in the midrib of the leaflets, and in the cells surrounding the sclerenchyma sheath of the midrib of the leaflets. This saponin-like substance was sometimes present also in the cells of the sclerenchyma sheath of the midrib. It differed from saponin found in the other parts in being less soluble in water.

The concentration of saponin in the cell walls suggests that it is concerned with the construction or composition of the cell walls. The frequent occurrence of saponin in association with sclerenchyma and xylem suggests that it may be especially connected with the elaboration of lignified and hardened tissue.

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EXPLANATION OF PLATES I, II.

The photomicrographs illustrate the structure of some of the tissues examined. Figs 1 and 4 were photographed with a 16 mm apochromat N A 0.3 and compensating ocular 8. Figs 2 and 3 were photographed with a 4 mm apochromat N A 0.95 and compensating ocular 4.

PLATE I

- 1 Transverse section of outer part of bark of branchlet 9 mm in diameter. The outer surface is shown in the uppermost part of the picture. Inwards from the surface the dark band of small cells traversed from left to right by a lighter portion is the periderm. Inwards from the periderm is the comparatively large celled cortex. In the cortex slightly towards the left is a group of sclerenchyma. Inwards from the cortex is the sclerenchyma ring which is composed of irregular groups of cells with ill defined or small lumina (cavities). The sclerenchyma with very small cells in the upper part of the sheath consists of thickened bast fibres in section. The sclerenchyma extends in irregular masses towards the lowermost part of the picture and is shown as pale in the photograph. The comparatively large, clear apertures in the lower half represent the sieve tubes in section. The dark, thick walled cells between the sieve tubes are bast fibres. $\times 100$
- 2 Radial section through outermost part of bark of branchlet 9 mm in diameter. On extreme right the surface of the bark is shown. Inwards from it is the periderm consisting of two series of small cells arranged in horizontal rows. Inwards from the periderm is the cortex consisting of large cells. The cortex is bounded on the left by the perpendicular band constituting the sclerenchyma ring, which is composed of highly lignified bast fibres and, on the upper left side, of stone cells. Some unligified parenchyma is shown on the lower left side of the sclerenchyma ring. $\times 170$

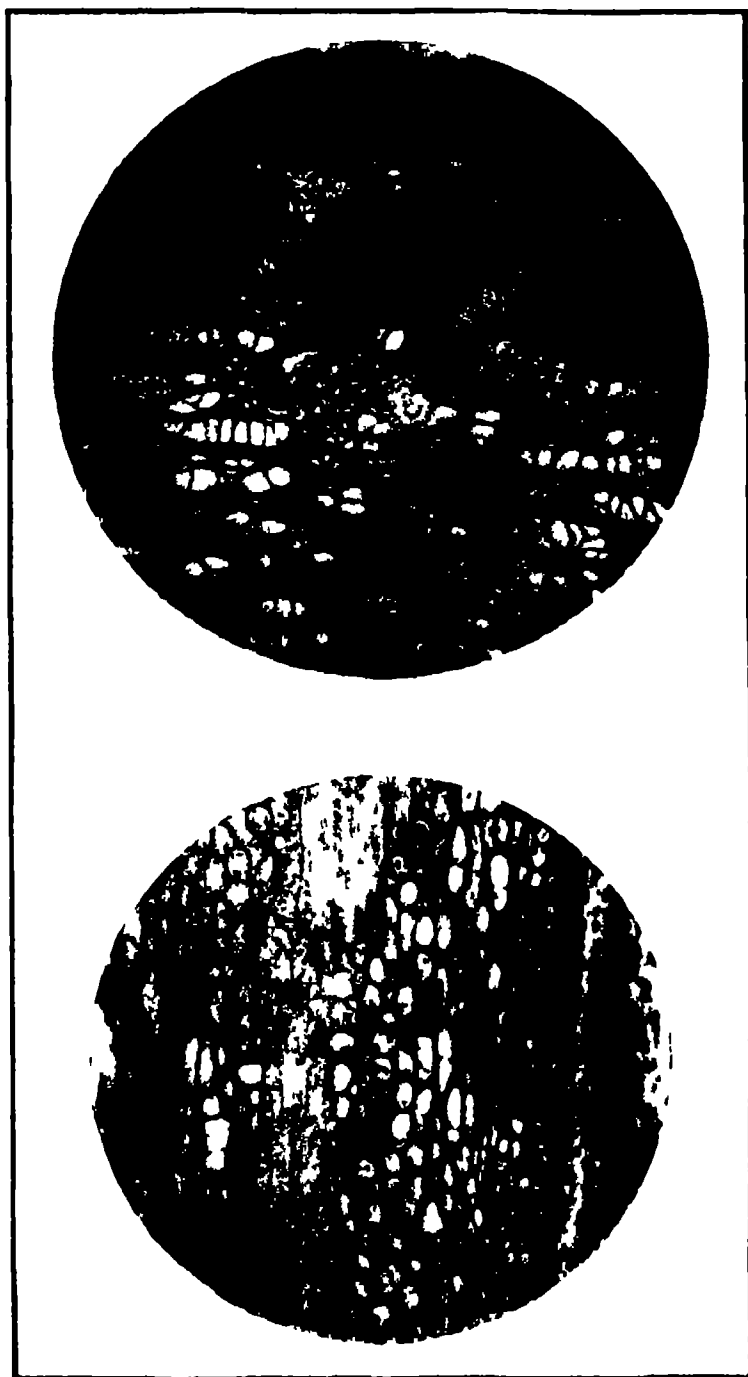


Fig 1—Transverse section of outer part of bark of branchlet of *Jageria pseudorhus* $\times 100$ Fig 2—Radial section of outer part of bark of branchlet of *Jageria pseudorhus* $\times 170$

PLATE II

- 3 Part of the same section the outermost portion of which is shown in Fig. 2. The outer part of the phloem is shown in this picture. The large, open, vessel-like elements passing from top to bottom of picture are sieve tubes. The sieve fields on the lateral walls of the sieve-tubes are indistinctly seen in places. Some bast fibres are shown between the sieve tubes on the right half of the picture. They are traversed in places by septa and accompanied by parenchyma which is shown towards the top and bottom. On the extreme left elongated parenchyma is shown. $\times 170$
- 4 Transverse section of secondary root 5 mm. in diameter showing outer portion. The broad, dark band in the upper part indicates the position of the periderm. Below it the cortex, consisting principally of very large cells, is shown. Below the cortex the irregular band of tissue composed of cells with ill defined boundaries is the sclerenchyma ring. In the middle of the picture the sclerenchyma ring is seen projecting inwards and flanking two large sieve tubes. Below the sclerenchyma ring the dark-celled tissue is the phloem in which the large apertures represent sieve tubes in section. The lowermost portion of the picture shows the wood. $\times 100$

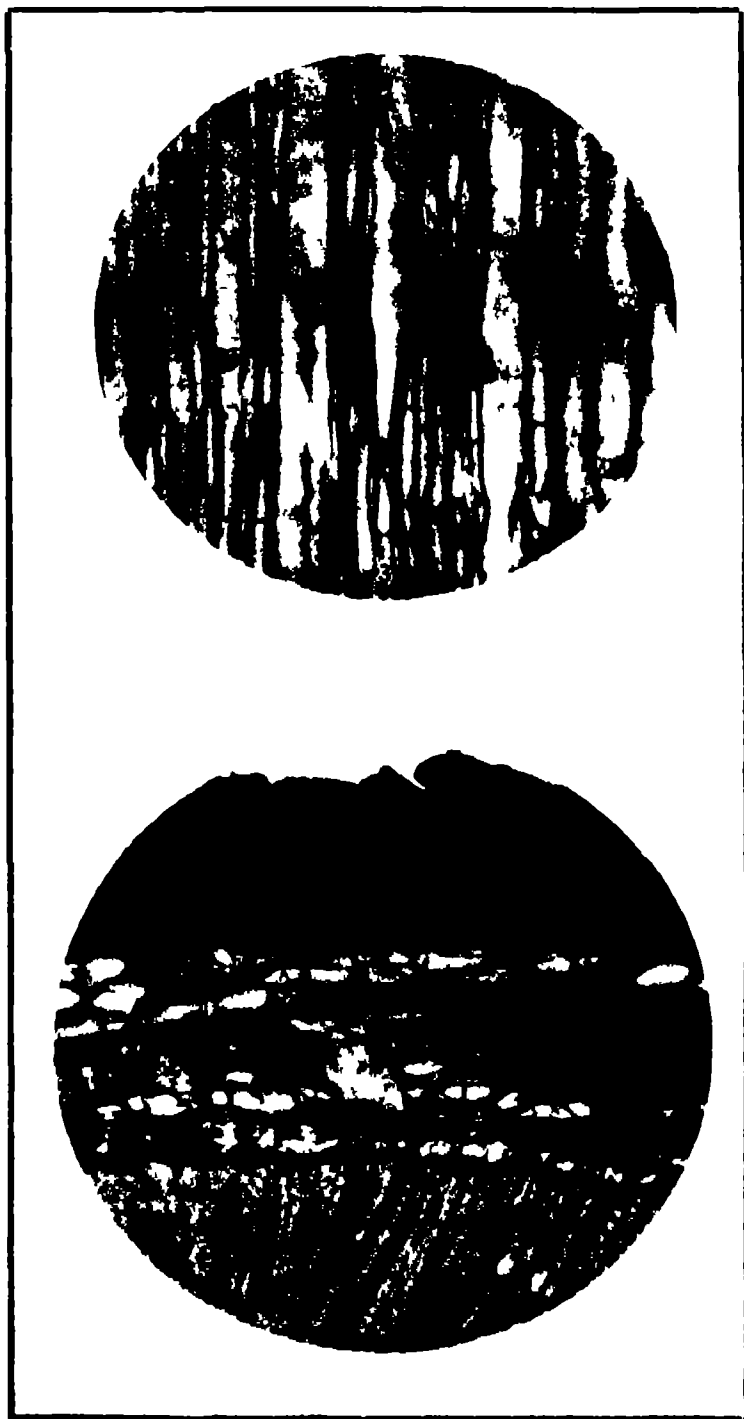


Fig. 3—Radial section of outer part of phloem of branchlet of *Jagaria pseudorhus* $\times 170$ Fig. 1—Transverse section of outer part of root of *Jagaria pseudorhus* $\times 100$

Revisional Notes on Described Australian Robber Flies of the Genus *Ommatius* (Asilidae).

By G H HARDY,

Walter and Eliza Hall Fellow in Economic Biology, Queensland University, Brisbane

(Placed before the Royal Society of Queensland, 25th June, 1928)

(Eight Text-figures)

THE illustrations of the genitalia given here are restricted to the lateral view of the upper and lower forceps and, when showing, the ventral plate. The lamellæ are sometimes hidden when viewed from this aspect, but invariably they are situated just below the dorsal process of the upper forceps when that structure is present, and it may be so found on the last four species described below. Care must be taken not to confuse the lamellæ with the outline of the parts illustrated when comparisons are being made. The shape of the genitalia, as exhibited by the eight species here given, exceeds in variety that of any other Australian genus I am acquainted with, there are up to five distinctive types, which suggests that the genus is a complex one, but the female ovipositor of all the species appears to conform to but one type that is not dissimilar to that of *Neoaratus*.

It would seem that White confused species to a certain extent, and so, when his material is re-examined, it may be possible to modify the synonymic references given here. The adjustments seem to be necessary under *O dimidiatus* and *O lema*, for the former is a very consistent form that White seems to have regarded as a variety of the latter, which itself is a species that varies in colour. Again a variation of *O. lema* was described by him as a distinct species. The synonymy regarding the other species seems to be clear enough, except perhaps that of *O vitticrus*, which, as known to me, may ultimately prove to be a complex of two very closely related species.

In the Gibbons collection, now in the Australian Museum, Sydney, there are four named species of *Ommatius*. *O distinctus* Ricardo, a paratype, *O angustiventris*, and two others under manuscript names, one being a specimen of *O dimidiatus* Macg, the other I did not identify at time examined, but as I think *O lema* Walker, it bears the number 9 on the pin.

PROCEEDINGS OF THE ROYAL SOCIETY OF QUEENSLAND

Key to the species of the genus *Ommatius*

- 1 Genitalia of the male with the upper forceps simple 2.
 Genitalia with one or more processes on the upper forceps 4
- 2 Upper forceps short and simple, the lower forceps much longer and with
 a process on lower edge *chinensis* Ricardo.
 Upper forceps much longer than the lower ones, lower forceps simple 3
- 3 Femora entirely black *angustiventris* Macq
 Femora only partly black *vitiosus* Big.
- 4 Upper forceps produced into a slender process that is broadened out,
 spatulate form, at the apex *dimidiatus* Macq
 Upper forceps with from one to three processes 5.
- 5 Upper forceps with one or two processes 6
 Upper forceps with three processes 7
- 6 Moustache entirely white One process issuing from the upper corner
 of the forceps *queenslandi* Ric
 Moustache with at least some black hairs The longer of two processes
 issues from the lower corner of forceps *pilosus* White
- 7 Upper process of upper forceps very slender and somewhat lamella like
 Intermediate process projecting well beyond the others Lowest
 process somewhat spatulate *lema* Walker
 All three processes subequal in length *distinctus* Ricardo

* OMMATIUS CHINENSIS Fab (?) (Fig 1)

Ricardo 1913, p 163

Ommatius chinensis Fab is an extra-limital form, and its identity with the one referred to by Miss Ricardo is not certain Ricardo recorded it from Queensland but she gave a very generalised description, and subsequently in Australian collections the name was wrongly attributed to *O vitiosus* Bigot There are two specimens before me that would appear to be that species described by Ricardo under the name one a female captured in Brisbane (November 1922) the other a male bred by G Bates Bundaberg (14.11.27) and sent for identification by Mr R W Mungomery who subsequently donated it to the Queensland Museum

The genitalia of the male on this species is so extraordinarily complicated that I have had difficulty in reducing its components to simple terms The upper forceps are two simple plates, rather well defined, but overlying the larger and more laterally placed lower forceps Ventrally from near the base of these lower forceps there arises a slender process that ends in a hook-shaped apex, and that is seen to cover what can only be regarded as the lower edge of the modified clasper The ventral plate is represented by a pair of horizontal and contiguous processes, slender, hairy, and somewhat palp like

OMMATIUS ANGUSTIVENTRIS Macquart (Fig 2)

Macquart 1849 p 89, Schiner 1867, p 410, Ricardo 1913, p 163
O corobus Walker 1849, p 472, and 1855, p 739

The synonymy was given by Ricardo. This common form is in nearly every collection, correctly identified. It is a black species with tibiae and markings on the thorax bright yellow. New South Wales is the only State in which it is known to occur.

OMMATIUS VITTICRUS Bigot (Fig. 3)

Bigot 1876, p. lxxxv, Ricardo 1913, p. 164. *O. machayi* Ricardo 1913, p. 165.

I think the above synonymy will prove correct. This form seems to be the common one of Southern Queensland, to which area it may be confined. Though quite distinctive in general colouration and appearance, very old specimens may be confused with *angustiventris*, but the leg colouration will distinguish it. All the legs have a black stripe on the otherwise yellow femora, or the hind femora may be black only at the apex. The specimen with the latter colour also has the abdomen entirely yellowish and the moustache entirely white, but it does not exhibit any marked difference in genitalia.

OMMATIUS DIMIDIATUS Macquart (Fig. 4)

Macquart 1849, p. 90, Ricardo 1913, p. 164, White 1916, p. 168.

It appears that this species occurs throughout the settled coastal area of Queensland, and extends into N. W. South Wales at least as far as Sydney. White's reference appears to be a complex, for he refers to a form on which the black is "on the posterior part sometimes reduced to an elongate spot", this character of the femora is consistent in my long series so it is possible that White had a small *O. lema* amongst his series of four specimens. Macquart described it from Tasmania in the fourth supplement but the locality is erroneous. Ricardo referred to it from North Queensland as "probably nearly allied" to *dimidiatus*, but there can be little doubt concerning its identity.

OMMATIUS QUEENSLANDI Ricardo (Fig. 5)

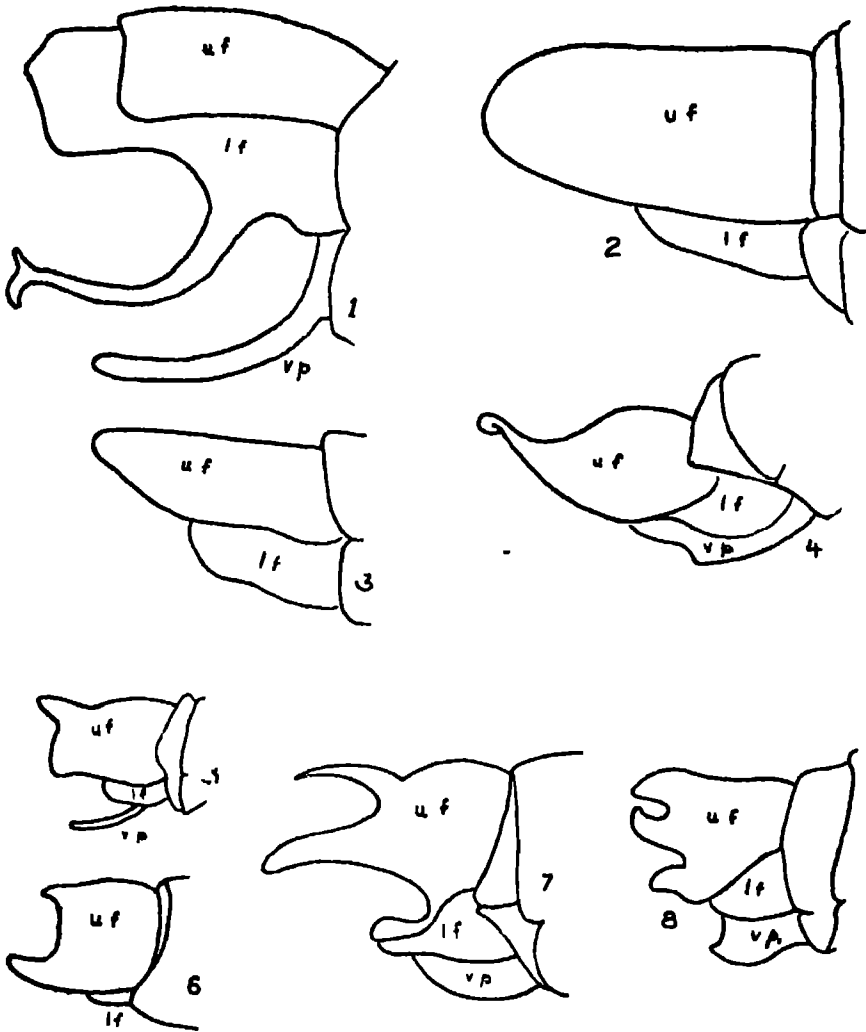
Ricardo 1913, p. 166.

A small black form that may be readily confused with one or other of the smaller species. Besides in the male genital characters, it may be recognised by the entirely white moustache of both sexes. The process on the upper forceps is somewhat small, and situated on the upper corner of the apical border, the apical edge of these forceps is bent inwards and has one, if not two, dentations along that edge, but these cannot be regarded as processes. There is only one pair before me (27th and 25th December, 1920), both from Brisbane.

OMMATIUS PILOSUS White (Fig. 6)

White 1916, p. 169, Hardy 1920, p. 186. *O. levis* White 1916, p. 170.

This synonymy was previously recorded by me. I have a sketch of the genitalia taken from the type of *O. pilosus*, and this conforms to



EXPLANATION OF FIGURES

Male genitalia of—

- Fig 1—*Ommatius chinensis* Ricardo
- Fig 2—*Ommatius angustiventris* Muquart
- Fig 3—*Ommatius vittatus* Bigot
- Fig 4—*Ommatius dimidiatus* Macquart
- Fig 5—*Ommatius queenslandi* Ricardo
- Fig 6—*Ommatius pilosus* White
- Fig 7—*Ommatius lema* Walker
- Fig 8—*Ommatius distinctus* Ricardo

lf, Lower foreeps, uf, upper foreeps, vp, ventral plate

that given here, the genitalia of specimens conforming to the description of the typical *O. levis* are identical. The species is as yet known only from Tasmania, but White added South Australia to its range, probably erroneously.

OMMATIUS LEMA Walker (Fig 7)

Walker 1849, p 472, and 1855, p 759, Ricardo 1913, p 164
O. obscurus White 1917, p 89

This synonymy is tentatively suggested, as I have not seen a specimen that fits White's description in every respect. The femora may be entirely black (*obscurus*) or the underside may be brown or red (*lema*), White may have included the latter as his *dimidiatus*. The red colour, when present, on the otherwise black femora is perhaps the one character that most readily distinguished the female from other species. Also the outer side of the tibiae is much lighter than the other parts of this segment, which again aids in the determination of the female, but the character is not confined to the species. In describing *O. obscurus*, White referred to the tibiae as being "brown at the knees". I have not seen this restriction, but he also states that the costal margin is tinged with brown, especially at the tip which wing character applies only to the present form.

All my specimens are from Brisbane, where it occurs somewhat abundantly from October to January resting on twigs, previously it was only known from New South Wales. This species can scarcely be the *dimidiatus* of Macquart, despite the fact Macquart states "legs red, femora above and tibiae below black" (Ricardo's translation), for he gives the dimensions as only 4 lines (about 8 mm) and states "Ailes claires".

OMMATIUS DISTINCTUS Ricardo (Fig 8)

Ricardo 1918, p 66

This species, hitherto only known from Queensland, is also represented from Darwin, Northern Territory, by one male. The form is readily recognised by the fuscous spot situated at the apex of the wing, but on the female the spot tends to disappear.

LIST OF WORKS REFERRED TO

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HARDY, 1920 — *Proceedings of the Linnean Society of New South Wales*, xiv
R S — E

A Geological Reconnaissance of Part of the Aitape District, Mandated Territory of New Guinea.

By H G RAGGIER, B Sc , Geological Survey of New South Wales
(One Geological Map and Section, Three Text-figures, Six Photographs)

Plates III , IV , and V

(Communicated by Professor H C Richards, D Sc , to the Royal Society of Queensland, 27th August, 1928)

INTRODUCTION

VERY little geological work has been done in the Mandated Territory of New Guinea, but recently several exploratory parties have been engaged in the search for oil, and a little has been added to our general knowledge of this large region

All such parties have encountered similar difficulties, many of which are common to geological work in any unexplored country, but some of which are peculiar to tropical regions in general and to New Guinea in particular. Chief of these are decreased efficiency due to trying climatic conditions, malaria, and the general difficulties of maintaining food supplies, communication, and transport.

In this paper are indicated, in a general way, the principal geographical and geological features of that part of the Aitape district of which the writer has personal knowledge, together with notes on adjoining areas. Six months were spent in continuous fieldwork in this district by a party employed by the Pacific Islands Investment Company of Sydney, consisting of Mr W A Chadwick, L S , Mr H A Robinson, surveyor's assistant, Mr R A Hanlin (in charge of food supply and transport), and the writer.

I am greatly indebted to the Pacific Islands Investment Company for permission to use information gained whilst in their employ. My thanks are due to Mr Tom Iredale for identification of shells, and to Mr W S Dun for remarks as to their general palaeontological aspect.

I am much indebted for corrections and useful suggestions to Mr E C Andrews, Professor H C Richards, Assistant Professor W R Browne, and Mr G D Osborne.

PREVIOUS WORK

Early coastal exploration of New Guinea belongs more to history than to geography or geology¹

Germany annexed the Territory in 1885 but until 1913 the exploratory work done was confined to the coast and the larger rivers such as the Sepik and Ramu

The Stolle and Cumberlege expedition mapped a large part of the Sepik River and its tributaries during 1913 and 1914, and it is believed that the Germans intended to push on vigorously with inland exploration, particularly with reference to economic geology and botany, but of course the Great War put an end to these activities

Since the Australian occupation, recruiters, traders, and patrol officers have been gradually pushing farther and farther afield

In 1917 Captain Macintosh investigated oil occurrences in the Smeu and Matapau areas, which lie about 40 and 45 miles, respectively, east of the limits of the accompanying map

In 1919 Lieutenant Young made a patrol south from Vanimo (about 90 miles west from Aitape), crossed the main divide, and returned to Aitape

During 1920-21 part of the Aitape district was examined by geologists of the Anglo-Persian Company. They confined their attention chiefly to Matapau and Ulau (*see* Map)

Government patrol officers have been over the coastal regions many times, and in 1925 an important patrol was carried out by Mr. A. Wilks into the region southward from Yakomul

Mr. R. A. Hahlin had previously made a recruiting trip into the district inhabited by the Wa-pu tribes, southwards from Aitape, and in so doing was probably the first white man to visit many of the villages in this region

The late Evan Stanley's report upon New Guinea makes general reference to the geology of the Aitape district, but no information is given on the map accompanying his report within the limits of the area examined by the writer. He also gives a summary² of the report of the Anglo-Persian Company's geologists on the Matapau area, and some general remarks upon the structure and disposition of Tertiary beds in the Aitape district

In the Matapau district the geologists of the Anglo-Persian Company noted the following sequence in the Tertiary sediments —

- (a) *Upper Group*—2,400 ft thick, foraminiferal mudstone, sandstone, and sandy mudstone intruded by diorite and granodiorite

¹ See Evan Stanley, "Salient Geological Features of the New Guinea Territory," 1922, pp. 7-11, 64-67. Aust. Encl., vol. II, pp. 22-24

² Evan Stanley, "Salient Geological Features of the New Guinea Territory," 1922, p. 66

- (b) *Middle Group*—2,300 ft thick, massive conglomerate interbedded with blue micaceous sandstone and mudstone (unfossiliferous). Conglomerates cemented with calcareous material
- (c) *Lower Group*—200 ft thick, blue micaceous sandstone, blue-grey mudstone, sandy mudstone, grit, and conglomerate

FIELD WORK—METHODS

Aitape, the administrative centre of the Aitape district, was naturally chosen as the base from which to carry out field investigations

Having no reliable map upon which to base a survey, it became necessary to attempt a reconnaissance of the entire area

The positions of the more important villages were fixed by Mr Chadwick, using theodolite observations in conjunction with wireless time signals for the determination of longitude. Intermediate points were fixed by joint time traverses and occasional prismatic compass traverses—e.g., Kapoam villages

In travelling from, say, A to B, where A is a fixed station, the position of B as given by the joint time traverses was plotted first. The position of B was then fixed, and the traverse corrected accordingly. There was never a very great error in the time traverses since each day's journey did not exceed about 10 miles, giving frequent accurate checks. Where possible the method of resection was employed also

Aneroid readings (checked where possible by theodolite observations, e.g. at Mendam) were used for altitude determinations. Graphs of diurnal variation were found to be most regular, and over long periods readings taken at the same hour each day for the same station showed little variation. Graphs for widely separated points generally had the same form (*see* page 73)

In addition to the survey and geological work, the names of prominent natural features and villages were obtained from the natives. The names which appear on the map have been spelled according to the Continental vowel system (as in French), and have been placed on the map regardless of the current pronunciation used by white people on the New Guinea coast, except that Aitape has been allowed to remain, because it appears on many maps of New Guinea as such

GEOGRAPHY

(1) General Features.

Aitape, the administrative centre of the Aitape district, is situated on the north-east coast of the island of New Guinea, about 100 miles south-easterly from the eastern boundary of Dutch New Guinea

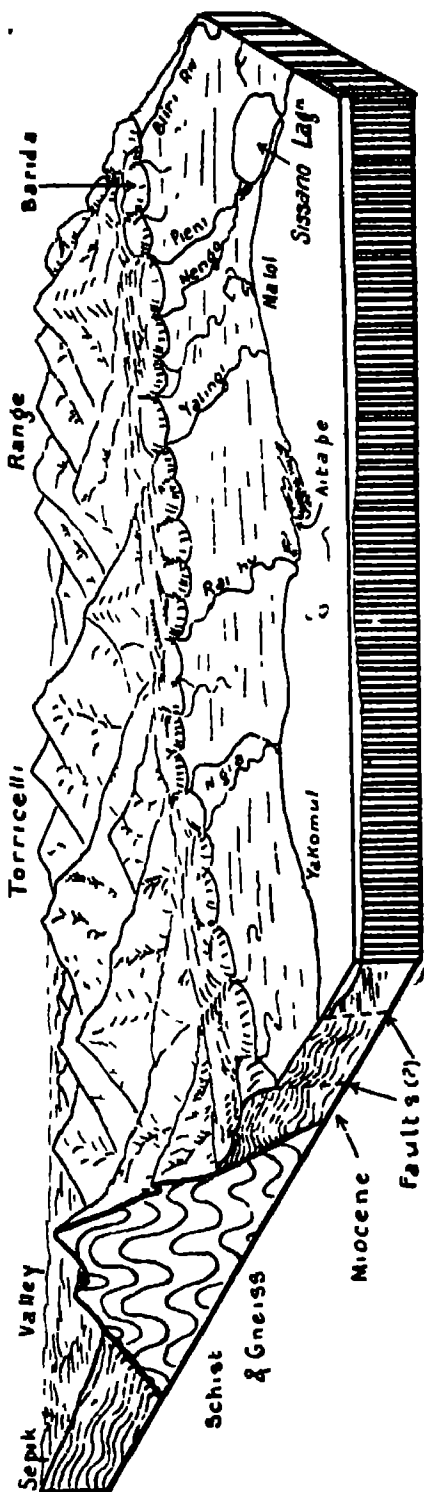
The area with which this report is chiefly concerned consists of approximately 1,000 square miles of country extending equally south-easterly and north-westerly from Aitape along a total coast-line of

70 miles, and inland about 30 miles from a coastal strip 22 miles wide, westerly from Aitape

The whole of the area lies north of 3 deg 30 min south latitude. The general geographical features of the area are as follow —

(1) *Coastal Plain*—The Coastal Plain is about 1 mile wide at Ulau, at Wom it is 4½ miles wide and it attains a maximum inland from Sissano, where its width is approximately 12 miles. It is for the most part low lying and swampy, but includes some low hills near the coast. The hills are confined to the western half of the area—namely, St Anna Mission, Aitape, Pultulul, Tepia. Considered as a percentage area of the coastal plain, however, these hills are insignificant.

The Coastal Plain is so little raised above sea-level that the large number of streams which flow through it inevitably meander as they approach the sea, in some places forming true deltas with numerous distributaries. The mouths of many of the larger rivers take the form of lagoons with a single entrance to the sea. In flood-time the crossing of these is very dangerous. The coast-line is practically straight. It trends about east-north-east, and has no large indentation throughout its entire length from the Sepik River to the Dutch border. With the exception of Vanimo, there are no deepwater bays of importance within the limits mentioned.



Block Diagram of Part of the Aitape District, showing the Principal Geographical Units—(1) Coastal Plain (Recent and Pleistocene Sediments), (2) Foothills (Miocene Beds), (3) Main Range (Schist and Gneiss), and (4) Inland Slopes (Miocene Beds)

(11) *Coastal Foothills*—The Coastal Foothills are a well-defined area between the plain and the higher land of the Main Dividing Range. The foothills rise directly from the plain. By this is meant that a line joining the fronts of the hills is relatively straight and sub-parallel to the coast-line. This is well illustrated on the map where the native paths (from Nengien to Aiterap for example) follow pretty closely the line of junction between those two geographical units, forming an approximate contour line 150 ft above sea-level.

The foothills have an average height of about 500 ft and attain a maximum of approximately 1,000 ft. Here the streams are deeply entrenched and relatively swift flowing (a rough estimate of the rate of flow of the Yalingi near Siauti suggests about 5 miles per hour). As the streams flow through the coastal plain they experience great loss in velocity, and their beds become filled with sandbanks and thickly strewn with snags in consequence. All the streams are liable to sudden floods (particularly at mid-afternoon), and during these periods it is inadvisable to attempt a crossing.

(111) *The Dividing Range*—In this part of New Guinea the Dividing Range does not exceed 5,000 ft in height. The highest point on the range south of Aitape appears to have been named by the natives "Subomoro". This point is close to the track by which the party returned from Wa-pi to Lupai, and on which the highest point reached was 4,600 ft (aneroid).

Except in its higher portions, the main range is clothed in thick jungle. There is a distinct lessening in the thickness of the undergrowth above 3,000 ft.

The party crossed the range in two places and both tracks may be described as distinctly dangerous, although it would be a comparatively easy task to make a safe pedestrian road across the mountains, following either route. The rivers are deeply entrenched, and in many places stream dissection is so advanced that the way leads across narrow ridges no more than a few yards wide, from which the ground falls away steeply on either side to depths of 1 000 ft or more.

(1V) *The Inland Slopes*—Southwards from about latitude 3 deg 25 min south, the hills are successively lower towards the Sepik Valley. Little is known of this portion of the area. In its more northern parts it is populated by the Wa-pi tribe, an industrious mountain people of good average physique.

The general features of the inland slopes are very similar to those of the coastal foothills.

(2) Topography and Drainage.

Some general idea of the topography has been given in the previous section. The coastal foothills and the inland slopes present many similar features, the outlook from Mendam and Epiop having many points in common.

From Epiop a good view can be obtained towards the main range of Papua, which on rare occasions may be distinguished with the unaided eye. The landscape consists of a number of separated parts from which the sharp angles of youth have been removed. There are few flat hilltops. These are replaced by sharp ridges along which native villages are forced to assume an elongated arrangement, and along which paths pursue a sinuous and hazardous course. It is a typical maturely dissected upland (Plate V, fig 2).

These remarks apply with almost equal force to the whole area, except, of course, the coastal plain. Only near their sources do the streams exhibit any of the characteristics of youth.

The mature topography of the main divide is responsible for a peculiar anomaly—namely, water shortage in a region of high rainfall. The run-off is immediate and complete.

The shape of the few hills in the neighbourhood of Aitape has been determined by the inland (southerly) dip of the rocks and their differential hardnesses. These hills have well defined slopes to the south, with scarps on the seaward side.

The coastal foothills have a general tendency to the same kind of feature in their more northerly parts, and dip-slopes are also particularly well developed in the inland slopes near Epiop. Here the bedding of the Tertiary sediments is exposed by land-slips, and may be seen to be approximately parallel to the surface slopes.

The stream pattern is interesting. The northward-flowing streams which drain into the sea are characterised by the absence of large tributaries. They all meander as they approach the sea, and some have true deltas. In plan they resemble trees devoid of branches for a considerable distance above the ground.

In a number of places tributaries enter the parent stream abnormally, so that there may be seen the phenomenon of two currents flowing in opposite directions in the one stream until the weaker is forced to turn and flow back with the stronger. A complete reversal of drainage during Recent time is suggested.

The Blun River is by far the largest stream between Smein and the Dutch border. It rises on the southern slopes of the main divide, flows north-westward, then turns northward and becomes part of the coastal stream series. The Blun (called Raimbrun at its mouth) must have been sufficiently well established to enable it to hold its course while the main range was being elevated.

Stream action since Tertiary time has been considerable. The few preserved sections of Post-Tertiary muds and gravels indicate a large amount of sedimentation. These beds have later been dissected and a vast amount of material must have been swept into the sea. Gravel-

strewn beaches mark the presence of stream mouths, in some places, for as much as a mile distant from the present points of entry of the rivers into the sea

Denudation of the land is still proceeding at a very rapid rate, but, over that part of the area where there is a fairly extensive plain bordering the coast, nothing but the finest silt reaches the ocean. In crossing the streams at their headwaters, one can feel a large number of pebbles being carried with the stream. Photographs of several of the coastal rivers show the extensive gravel-beds, which are being built up by the coastal streams throughout the foothills (Plate V, fig 1)

(8) Climate

The area, as already stated, lies north of 3 deg 30 min south latitude, and the climate is therefore tropical

In one word, the outstanding feature of the climate may be described as monotonous. Compared with temperatures to which Australians are accustomed, the mean temperature is low, but the humidity is much higher. The monotony of the climate is not so marked in the mountains, which also seem to be free from malaria. A trip to the mountains is distinctly invigorating to persons living on the coast. Periodic visits to a higher region would undoubtedly make life less irksome for those living in the coast districts. The late Evan Stanley has also stressed this point more than once.

The temperature and humidity figures are not available for Aitape district, those of Madang, the next adjoining district easterly from Aitape, being given instead, as likely to be very similar.

Month	Dry Bulb, 9 a.m.	Wet Bulb, 9 a.m.	Humidity per cent	Mean Maximum Temperature	Mean Minimum Temperature	Mean Temperature	Highest Temperature	Lowest Temperature
January	81.8	77.0	80	88.0	74.3	81.2	91.8	68.0
February	81.2	76.6	80	87.5	74.1	80.8	92.0	71.0
March	81.3	76.8	80	86.7	74.0	80.4	92.0	71.0
April	81.4	77.4	83	87.3	74.0	80.6	92.0	70.0
May	81.6	77.3	82	87.4	74.2	80.8	92.0	71.5
June	81.5	77.0	81	86.9	73.7	80.3	91.5	69.0
July	81.3	76.9	81	86.7	74.3	80.5	92.2	70.0
August	81.0	76.7	77	86.9	73.9	80.4	91.0	70.0
September	82.3	77.2	79	87.7	74.2	81.0	92.5	70.3
October	82.7	77.4	78	87.2	74.1	80.6	92.0	70.0
November	82.4	77.4	79	87.7	74.2	81.0	91.7	70.5
December	82.2	77.2	79	87.7	74.3	81.0	92.0	68.5
For the Year	81.8	77.1	80	87.3	74.1	80.7	92.5	68.0

These figures are for the seven-year period ending 1924. It will be noted how little the humidity percentage varies from month to month from the yearly average, the average being 80 per cent, the minimum 77 per cent, and maximum 83 per cent.

The monotony of the climate is further emphasised by a study of the temperature figures. The minimum and maximum temperatures for each month are practically the same, and the difference between the maximum and the minimum over the whole period is only 24.5 per cent.

According to the official figures,⁴ Aitape has the lowest rainfall for all districts in the New Guinea territory, but the figures are somewhat misleading if they are taken as being representative of the whole district. It should be noted that Aitape is situated on the coast some distance from the mountains. As the high land is approached the rainfall progressively increases. For instance, in the wet season, a village such as Wanigi experiences heavy rain practically every afternoon between 2 p.m. and 4 p.m., and a tropical thunderstorm may be heard raging over Lupai and Wanigi, whilst at Wom, at the foot of the hills, only very slight showers may be falling. In this connection compare the rainfall of Rabaul (average 86.19 in.) with Talasea (average 169.85 in.) and Gasmata (average 169.85 in.)

During 1923 the rainfall at Aitape amounted to 96.70 in., the average for three years being 85.85. (The average annual rainfall of Byron Bay, N.S.W., is 77.41 in.)

In the Aitape district the dry season, extending from July to November, is characterised by mild south-east winds, north-west winds commence towards the end of November and continue throughout the wet season until June or July. In the wet season it is advisable to try to reach the village selected as the objective for the day, in advance of the usual afternoon storm. This, as a rule, does not last very long (something like half an hour) and work may then be resumed in the vicinity of the village.

Previous remarks concerning the aneroid barometer and the general incidence of the afternoon storm are illustrated by the following figures —

Aitape (500 ft. A.S.L.)		Mondam (1,550 ft. A.S.L.)	
Time	Aneroid reading in feet	Time	Aneroid reading in feet
A.M.		A.M.	
10 30	1,460	8 0	2,375
11 30	1,500	9 0	2,390
P.M.		10 0	2,400
12 30	1,525	11 15	2,350
1 30	1,550	Noon	2,350
2 30	1,575	P.M.	
3 30	1,610	1 0	2,400
4 30	Storm	2 0	2,425
4 45	1,575	2 15	Storm
5 30	1,560	2 30	
6 30	1,550	3 0	2,390
8 30	1,450	4 0	2,380
9 15	1,450	5 0	2,360
		6 0	2,360

⁴ Dept. of Agriculture, Man Yerr New Guinea, Leaflet No. 44.

(4) Vegetation.

So far as vegetation is concerned, there are two sharply contrasted types of country in New Guinea, namely forest and grass lands. The whole of the area actually travelled over during this investigation consists of forest. "Kunai" or grass lands are common around Rabaul and eastwards from Aitape, notably about Monumbo (Potsdamhafen). Inland from this locality there are large areas of "Kunai," this grass constituting practically the sole building material used by the natives.

Looking down towards the Sepik River from Epiop there are vast areas to be seen which probably consist of "Kunai" or some similar kind of grass.

The forest or jungle growth appears to be very similar from sea-level to about 3,000 ft. Above that level there is marked thinning in the undergrowth. Here the ground is carpeted with beautiful ferns and begonia-like plants which must be trampled upon at every step. The trunks of the trees are covered with mosses and lichens. Palms are rare, and appear to be all of the type known to the natives as "limbong." This palm is used in many ways. The trunk is split into sections and used for floors and sides of houses. The leaves are used as thatch, and in time of emergency the succulent parts may be used as food.

In the jungle it is impossible to diverge from cut paths. The trees grow thickly together, the ground is obscured by dense undergrowth, and vines grow thickly over all. Calamus and D'Albertis abound. The trees are decorated by staghorns and graceful orchids, and the ground is littered with decayed and rotting vegetation and brightly coloured native fruits. Swamp areas are invariably occupied by the sago-palm (sac-sac).

There is abundant softwood timber available for the erection of temporary dwellings and shelters, but hardwood trees such as Quila and Afzelia are not plentiful, except in certain sections.

(5) Settlement, Communication, and Transport

White settlement is confined to the coast, and practically all the transport of goods from station to station is done by schooner.

Extensive native settlement exists on the beach and to a lesser extent on the seaward side of the coastal foothills, but over practically the whole of the coastal plain there are few native villages. The main divide is almost uninhabited. On the inland slopes again there is a large native population. Much might be said upon the very definite control which the geography of the region has exercised upon the distribution of population.

There is a coastal "road" (such being the "pidgin" term universally used for any kind of track) which traverses the whole of the seaboard. The "road" is a path from one to two yards wide, which is kept cleared

by natives for certain allotted distances each side of the various villages. About Aitape itself where there is no native village the work is done by prisoners.

It is possible to travel over the coastal track on horseback, but there are many river crossings which necessitate frequent delays. Over certain sections of the coast bicycles may be used, but this means of travel is only practicable during the south-east season, when wave action is at a minimum and the beach sand has had time to consolidate. Even then a bicycle can be ridden over the greater part of the beach at low tide only. A bicycle may easily be placed in a canoe and ferried across the rivers. The party found the bicycle useful in some places, notably between Aitape and Arop. At only four points on the whole of the coast line between Smein and Sissano, a distance of 75 miles, are there headlands which bar progress along the beach.

The question of road construction across this country will be full of difficulties. In the coastal parts there are many sago swamps to be crossed, and the meanderings of senile streams will require the construction of a considerable number of bridges, or the diverting of the streams to other courses. It must be also remembered that these streams are subject to frequent floods.

The advanced dissection of the uplands also introduces engineering difficulties, which would require costly works in land lines of communication, even in a country otherwise well adapted to white settlement.

GENERAL GEOLOGY

Summary of Stratigraphy

The summary given below may be considered as a provisional classification of the rocks exposed within the area examined, but it probably applies to neighbouring localities also.

Recent and Pleistocene—

- (1) Coastal Deposits—Estuarine and river beds, river gravels, sands, and muds
- (2) Matapau Coralline Limestone—Limestone interbedded with pyroclastic deposits and muds
- (3) Mau River conglomerate and muds

Unconformity —

Late Tertiary (probably Pliocene)—

- (4) Aitape Beds—Approximately 5,000 ft thick, limestone and volcanic rocks
- (5) Mendam Beds—Conglomerate, sandstone, and agglomerate. Thickness not determined

Disconformity —

Tertiary (probably Miocene)—

- (6) Yalingi River and Ulau Beds—2,500 ft thick Blue micaceous mudstone, alternating shale and sandstone
- (7) Aiterap Beds—750-1,000 ft thick Chiefly thickly bedded mudstone
- (8) Bliri River Beds—Shale, sandstone, and limestone

Unconformity —

Pre-Miocene (possibly Mesozoic)—

- (9) Older altered sediments—Crystalline limestone, indurated claystone, and slate

Pre-Cretaceous—

- (10) Schists and gneisses of the Main Dividing Range

Note—The Bliri River Beds (8) are more compact than those of (6) and of (7) and the fossil evidence suggests greater age. Possibly (6) and (7) should be placed in the Pliocene, or they should remain in the Miocene and (8) be tentatively classed as Oligocene⁵ (*See also pages 86-87*)

(1) *Coastal Deposits*—Apart from the muds and river gravels which form the low-lying area behind the beaches there are several points at which shell-beds have accumulated and have since been raised from a few feet to about 8 ft above sea-level. Shell-beds are to be seen at Ulau, St Anna Mission, Pultulul, Ulau, and Tepier Plantations

(2) *Matapau Coralline Limestone*—At Matapau, raised coral occurs, overlain by mudstone. In some places this sequence occurs more than once, interbedded with pyroclastic deposits. These beds rest with marked unconformity on the Miocene mudstones, and the amount of uplift indicated is about 8 ft

(3) *Mau River Beds*—The river-conglomerate and mud at the junction of the Yalingi and Mau Rivers rest on the eroded Tertiary rocks with marked unconformity. The beds are about 70 ft thick. Similar beds occur in the Wiwa and other rivers

(4) *Aitape Beds*—The geological age of the Aitape beds is largely conjectural. The outcrops to be seen at the present day are but a remnant of a much more extensive series. The geological relationships existing between this series and other rocks in the Aitape district are entirely obscured by recent deposits. These beds are referred to the later Tertiary because they are certainly older than the Pleistocene raised coral and because of the occurrence in them of volcanic rocks similar to those found at Moron and elsewhere in New Guinea

⁵ Oligocene and Eocene beds are said to occur on the north side of the Bewani Mountains, which adjoin the Torricelli Mountains (*Aust. Ency.*, vol. II, p. 25)

(5) *Mendaw Beds*—These beds are well exposed in a gorge at the head of the Pieni River. They consist chiefly of coarse sediments overlying mudstone and sandstone disconformably.

(6) *Yalingi River and Ulau Beds*—These consist in part of sandstone and fine conglomerate with mudstone beds, and of alternating shales and sandstones. Details of this series as exposed in the Yalingi River near Waningi are given on page 80. There are also exposures of blue sandy mudstones in the Tomoflu River near Romi, and in the Oi River near Walwalli, containing fossils similar to those obtained near Ulau. Fossils are abundant in certain zones in all the exposures of these beds. The only actual surface evidence of the occurrence of oil within the area is the Lupai spring which issues from recent mud deposits overlying the Yalingi River beds. The series is lithologically ideally adapted for the accumulation of petroleum.

(7) *Aitrap Beds*—The Aitrap beds constitute a very thick mud series with no particular features of interest. There appear to be two facies—

- i. A lower group of yellow-brown mudstones, calcareous towards the top.
- ii. An upper group of blue micaceous mudstones.

(8) *Blini River Beds*—These beds consist of shale, sandstone, and limestone, the latter being more abundant towards the top of the series. The limestones are fossiliferous in places. They outcrop in the headwaters of the Blini and Wini Rivers. Possibly the limestones in the Wiwa River may belong to this group.

The shale and sandstone form a series of thin beds alternating with each other. No estimate of thickness of the series has been given, but judging by the exposures high above the bed of the Wini River it is at least several hundreds of feet.

(9) *Older Altered Sediments*—In Bulletin XIII of the Imperial Institute (on page 567) reference is made to the occurrence of Cretaceous beds in the Torricelli Mountains,⁶ and the late Evan Stanley indicated an area of Cretaceous rocks on his geological map of the New Guinea Territory. There appears to be a group of rocks both north and south of the divide which has not been subjected to the same amount of alteration as the schists and gneisses of the Main Dividing Range. Slaty and serpentinous rocks occur on both sides of the divide, and Mr. Wilks, patrol officer, has collected slate with *augen* of quartz southwards from Yakomul.

A Mesozoic age has been assigned to similar beds in New Guinea and Papua, and may perhaps be accepted tentatively here. A verification of the existence of Cretaceous rocks may fix the age of these and similar beds quite definitely.

⁶ Also referred to in Aust. Ency., vol. ii, p. 25.

(10) *Main Range Schists and Gneisses*—The schists and gneisses of the main range are well exposed in the headwaters of several of the rivers. These are discussed in some detail on page 83. The only geological age which can be assigned to these beds with any certainty is Pre-Cretaceous.

Description of Localities.

The geography of the area is a direct expression of the geology, and the latter may therefore be conveniently described under the headings adopted in the discussion of geography.

(1) *Coastal Plain*—As already mentioned, there are very few outcrops to be observed throughout this portion of the area. For the most part it consists of mud and clay with some sands and river gravels.

In the vicinity of Aitape, in the hills previously mentioned, a limited number of outcrops occur, extending from St. Anna mission to a small headland north-westerly from Tepier plantation. In the St. Anna mission the outcrops consist of limestone, with thin beds of volcanic breccia. Aitape headland is made up of limestone capped by volcanic agglomerate. The agglomerate in turn appears to be overlain by a vesicular lava much traversed by veins of calcite. The upper part of the series is repeated at Pultulul, where some thin limestone beds are also included. In the headland at Tepier plantation, volcanic rocks attain a maximum and the limestone beds are insignificant. The headland consists almost entirely of a coarse agglomerate. This agglomerate is underlain by a volcanic rock of trachytic type, as is shown by the exposures in the rocks which outcrop in the sea, between Tepier plantation and the new village of Marok. It is also overlain by a lava somewhat more basic.

From its general disposition in relation to the headlands on the mainland there can be little doubt that the volcanic rocks outcrop both on the island of Tomleo and in the small islands (Ant Rock, Oyster Rock, &c.) between Tomleo and Aitape. The rocks there evidently dip in the same direction and at the same amount as those in the vicinity of Aitape—namely, S 15 deg E at 20 deg (Plate III, fig 2).

From the above description it appears that all these rocks form part of a conformable series, in which the limestone attains a maximum thickness at Aitape and rapidly thins out laterally east and west. There are very few fossils in these beds.

The other two remaining outcrops, in the coastal plain at Malol and Sissano, consist of limestone very similar lithologically to that already described.

(2) *Coastal Foothills*—Tertiary rocks outcrop over practically the whole of the coastal foothills. It is proposed to discuss these rocks under localities.

(a) *Uluu*—Uluu is a large coastal village at the eastern end of the area examined. The Damayien River flows through part of the village and

may be examined throughout the whole of its course, a distance of about 4 or 5 miles. Where the Nundrawada and Damayien meet they are already practically at base-level, and are forced to spread out again in order to carry the greatly increased volume of water which comes down from the mountains after heavy rain. They enter the sea through three distributaries, of which the easterly one is the most important.

About 2 miles from the beach and at the junction of these two streams, Tertiary rocks are exposed. They consist of andesitic lava, mudstone, and sandstone in the form of a syncline the axis of which strikes N W and S E. Where these rocks abut the older rocks of the divide, they are sharply folded. (See Section, page 84.)

Fossils were obtained from a bed some 5 or 6 ft thick. They were fairly abundant but difficult to secure as complete specimens. These beds are very similar in general appearance to those exposed at Matapau.

(b) *Nigia River* — The Nigia River flows for the greater part of its course across Tertiary beds. The fact that a large oil seepage had existed near the village of Chinapelli and had been covered by a recent landslide could not be verified, the natives disclaiming knowledge of its existence.

Specimens of rock collected by Mr. Adam Wilks, patrol officer, from near Chinapelli, show that the divide here consists largely of the same rock types (chiefly slate with *augen* of quartz) which occur on the flanks of the main range near Lupai, and which are certainly too old and too much altered to yield anything of importance from the point of view of Petroleum Geology.

(c) *Kapoam District* — In the low divide between the Nigia and Raihu Rivers, Tertiary beds outcrop in the form of sandstone, fine conglomerate, and thin beds of mudstone. The little evidence available suggests the structure of a pitching anticline with its axis approximately N N W. At Paiawa the rocks exposed have been completely altered to a bright red clay. The clay suggests the volcanic rocks near Aitape, and it may be that the Tertiary beds are intruded at this point.

(d) *Raihu River* — In the headwaters of this large river the predominant outcrops are mudstone, with some sandy, pebbly, and tuffaceous beds, though in the upper waters of the Wiwa River prominent beds of limestone occur interbedded with mudstone. They appear to be unfossiliferous at this point. The bed dips southerly, the amount of dip being generally about 15 degrees.

In the Wiwa River near Osi the mudstone is intruded by a rock of dioritic type, and the beds are practically vertical. A sulphur spring occurs near Levaiti, and this appears to be associated with late or Post-Tertiary intrusive rocks. One may note that at Matapau, oil seepages are associated with sulphur-bearing springs in an anticlinal structure intruded by granodiorite. Possibly there are other intrusions in the Raihu valley.

(e) *Asterap-Siauti Area*—At Aiterap a thick mudstone series outcrops. It includes a few thin beds of limestone. Many bars in the creeks in this locality are covered with a deposit of secondary limestone or tufa. Owing to the presence of marked jointing and the absence of distinct bedding planes, it is difficult to determine the dip of the beds. They appear to dip steeply to S E, but this is not quite certain. Towards Wom (the local dialect name for Coconuts) the mudstone series becomes calcareous and in places might be described as earthy limestone. At Wom the prevailing dip appears to be southerly. In the Peli River, the mudstone, as at Ulau, is blue and micaceous and in places sandy. There are also sandstone beds which are valuable in indicating dip. The beds are folded into anticlines and synclines, the axes of which strike approximately E and W.

The Peli is a small stream which is lost in swamps soon after entering the coastal plain. Its deflection eastward, near Siauti, is due rather to the obstacle provided by older river gravels from the Yalingi than to adjustment to structure, as might be concluded from the map.

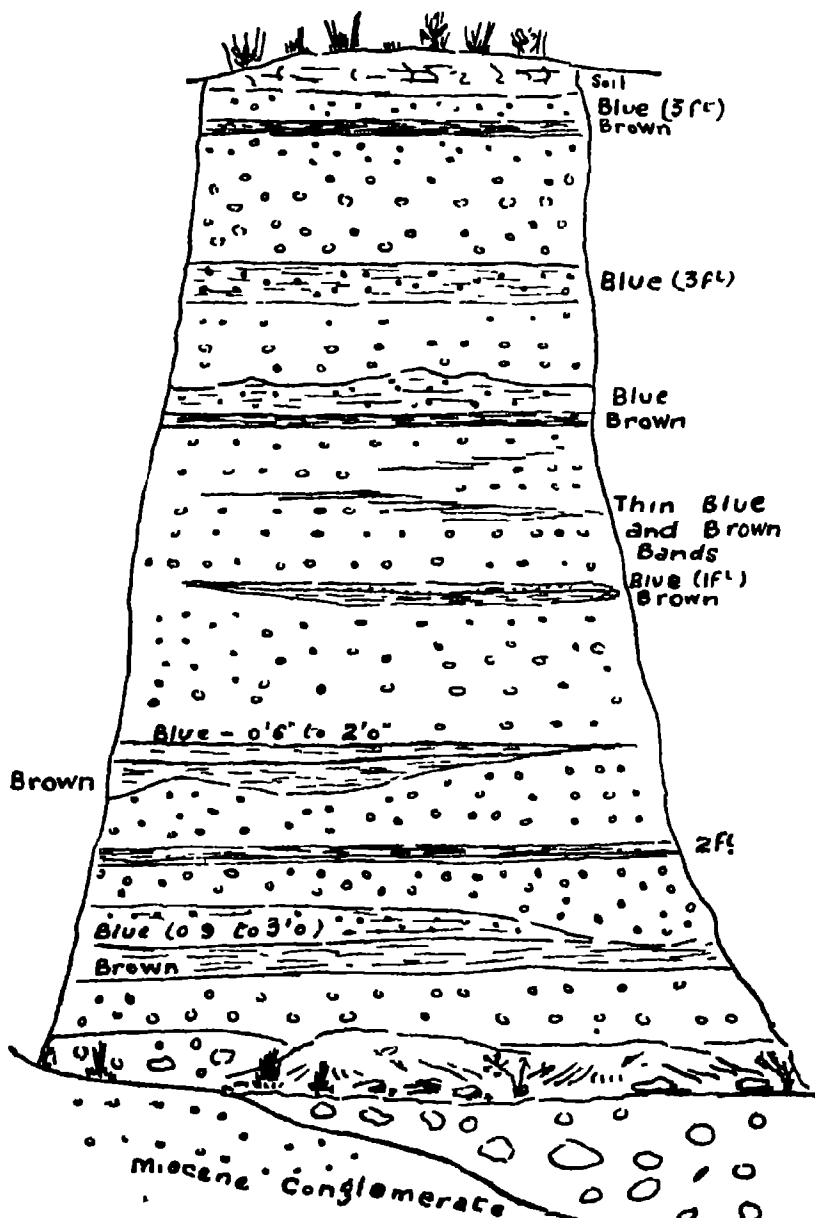
The natives of Wom obtain some of their salt water for cooking purposes from a brine-soak in the blue micaceous mudstones, but little importance can be attached to the occurrence of brine at this point. The water is certainly not as salt as that of many creeks which flow over marine rocks in the Permian-Carboniferous system of New South Wales. Upstream, sandstone beds become more numerous, and there are several beds of fine conglomerate which amount in some places to quartz-conglomerate.

(f) *Yalingi River*—The Yalingi River in part of its course reveals a somewhat similar section to that exposed in the Peli, but the Yalingi is a large stream and the information is more complete.

The Yalingi River flows practically due south for a distance of 8 or 9 miles, exposing a section of Tertiary rocks. The lowest members of the rocks exposed consist of the blue micaceous mudstone, previously mentioned. These beds are traceable to a point in the river about 1 mile south from the new village of Waningi, where sandstone beds are to be seen (dips S at 19 deg, and S W at 12 deg). Sandstone and mudstone in alternating beds 2 to 16 in thick form the outcrops to about a mile upstream from Waningi. An excellent section some 35 ft high is exposed by a waterfall close to the main stream. Fragments of fossils obtained resemble those from Ulau. Sandstone and fine conglomerate overlie this stage (Plate IV, fig 2).

The structure is that of an asymmetrical anticline, which dips steeply on the northern side of the axis and more gently (12 to 20 deg) on the southern. This structure is modified by a bulge or low dome near Waningi. At Lupai, mudstones outcrop, dipping 8 deg N. These are also interbedded with sandstone. A syncline is indicated between Lupai and Waningi. South from Lupai a second anticline is developed more

nearly symmetrical and more gently dipping than the first. The dip rapidly increases from 7 deg near Lupai to 25 deg in the Mau River. At the junction of the Mau and Yalingi Rivers an excellent section of Pleistocene or Post-Tertiary beds is exposed by a landslide. These muds and river conglomerates form a vertical face about 70 ft high, and they rest on the eroded edges of Tertiary rocks. The following section is exposed —



Section of Post Tertiary Muds and Gravels—Junction of Mau and Yalingi Rivers
 R.S.—F Height, 70 feet. Approximately to scale.

It will be noted that pebbles occur throughout the section, but that they are less abundant and smaller in size in the mud-layers. Nearly all the mud-layers exhibit the same characteristics—namely, a brown mud at the base overlain by a blue mud with small pebbles towards the top. There are in all eight pairs of blue and brown muds which vary in thickness from 9 in to 3 ft (Cf Plate IV, fig 1)

To examine the causes giving rise to this section, in detail, is beyond the scope of this paper, but some suggestions may be made. There is evidently some rhythm to be considered. The blue (or grey) beds probably owe their colour to iron disulphide, the brown, to mixtures of hydrated ferric oxides, indicating that the former have been subject to marine (anaerobic) conditions sufficiently long to enable conversion of the hydrous oxides into sulphides. The gradual change from marine to shore-line or terrestrial conditions is indicated by the presence of pebbles in the mud-layers overlain by conglomerate.

(g) *Pieni and Nengo Rivers*—In the Nengo River the mudstones are underlain conformably by volcanic agglomerate (dip, E 20 deg S at 50 deg), which is therefore the lowest bed in this section of the Tertiary sediments. Mudstones outcrop throughout the lower part of the course of the river, interbedded with thin strata of limestone and tuff. About 2 miles above the junction of the Numella and Pieni, sandstone and conglomerate beds make their appearance. The junction appears to be disconformable, and the beds above the disconformity are different from anything previously observed. The conglomerates are much coarser, and there are occasional beds in which the fragments are angular. The latter become more and more numerous higher in the series, and the final stage is dominantly agglomeratic.

It will be noted, by reference to the map, that the maximum folding is at the northern end of the section, which indicates that the folding force was directed against the beds from that quarter.

(h) *Bhri or Rambrum River*—This river is the largest on the Aitape coast. A glance at the map will show that for a distance of 12 miles from its mouth the river flows through a low-lying area of jungle and swamps.

The mountain at Barida is composed almost entirely of mudstone. There are a few sandstone and limestone beds. The occurrence of tufa deposits derived from the latter may also be noted. The beds dip to S and S W at angles which vary from 27 to 45 degrees.

In the Neni River, near Romi, sandstone and fine conglomerate outcrop, and at the junction of the Ebleh and Bhri Rivers the limestone bed in this section is in evidence. Thence the section to Karandu exposes mudstone, sandstone, and limestone, the latter more and more strongly marked as the river is ascended. It is compact and non-fossiliferous, and the exposures strongly suggest the Wiwa River section near Osi.

¹ See Twenhofel, "Treatise on Sedimentation," 1926, pp 543-550, for general statement and for further references.

Immediately above Calau the Tertiary rocks are intruded by igneous rock, steeply folded, and, in places somewhat altered. So far as can be seen the intrusion appears to be sill-like in type.

Below Morlu interbedded sandstones and shales outcrop in the river bed. The bedding planes are practically vertical. Between Morlu and Durali only river gravels are to be seen. These contain numerous pebbles of coralline limestone, of Tertiary age, derived from the foot of the main range above Durali. There must be a considerable thickness of these gravels corresponding to the rocks of Post-Tertiary age at the head of the Yalingi River. (See also "(4) *Inland Slopes*")

(3) *Dividing Range*—The Dividing Range is composed for the most part of altered rocks of both sedimentary and igneous origin.

After leaving Mendam one passes over crystalline limestone and indurated claystone. The central portion of the range is composed of schists intruded by a rock of dioritic type. The latter is in turn intruded by porphyry. On the southern side of the divide the road leads over thick beds of crystalline limestone for some distance. Here again fossils appear to be absent.

At the head of the Mau River above Lupai, the Tertiary beds rest unconformably against a series composed of gneissic rocks of great variety. Acid types with basic *schlieren* are of common occurrence. A thick band of dull red jasper, traversed by numerous veins of quartz, was also noted.

The southern side of the divide (Wapi) consists largely of altered sediments, chiefly schists with many isolated lenses of quartz.

All the original characters of these beds have been destroyed. It is certain they are Pre-Tertiary in age. The more highly altered may be Pre-Cretaceous, but the criterion of degree of alteration is capable of leading one into great error, and its value in the determination of geological age in New Guinea has been much over-estimated.

(4) *Inland Slopes*—In the headwaters of the Blun River, near Maiwetti, there is exposed a considerable thickness of Tertiary beds. In places fossils are abundant, though largely fragmentary. The beds from which the fossils were obtained vary from mudstone to sandy shale. These are overlain by tuffs, grits, and conglomerates.

Similar beds outcrop on the path between Maiwetti and Yongiti. In the Wini River, below Yongiti, shales interbedded with sandstones are exposed. At one point a landslip reveals a face 50 ft high which is made up of four sandstone beds 2 ft thick, separated by beds of shale 10 to 12 ft thick.

All the rocks exposed in this portion of the area dip relatively gently, and they present many features in common with beds on the northern side of the divide. They appear to be somewhat more compact, however.

Structure

The structure of the area is not complex. It will be seen by reference to the map that the geology is such as to preclude a very close analysis of folding movements during Tertiary time.

The relationships existing between the Aitape Series and the Miocene beds of the coastal foothills is not likely to be made out in the field without the assistance of information obtained from bores, and in the absence of detailed palaeontological evidence the relative age of these beds and the movements affecting them must remain in doubt.

The main folding movements, of which there is undoubted evidence, took place in Post-Miocene or Late-Miocene time. The Tertiary beds both north and south of the divide exhibit similar structures, and appear to have been subjected to the same fold movements although possibly not to the same degree.

The folding of the rocks is directly related to the uplift of the mountains which extend sub-parallel to the coast-line. The main axis of folding extends W N W and E S E, and the intensity of folding decreases from the mountains, seawards, and from the mountains towards the Sepik River. The following diagrammatic section at Uluu may be taken as typical for both north and south sides of the Main Dividing Range —



Diagrammatic Section, Damayien River, Uluu

The general section from Tomleo Island to Towati also shows the general structure of the area (*See map*).

The coast-line and the line of junction of the foothills with the coastal plain form two nearly straight sub-parallel features, which suggest faulting. There is no direct evidence of this, but as each of these features has been developed in, at the oldest, Post-Miocene time, and is in turn approximately parallel to the main coastal range, faulting is at least suggested.

Geological History and Phynography.

It is fairly evident that, in Tertiary time, very little of the present land surface was above the sea. Probably the older metamorphic series emerged as a line of narrow islands. The limits of this sea lay beyond the area examined north and south of the Main Dividing Range.

The thick mud-series which occurs at Aitapap and other places suggests deep, still water. A period of uplift followed, the mud-beds being overlain by marine and deltaic deposits consisting characteristically

of blue, micaceous, and sandy mudstone. Fairly regular rhythms in the general uplifting movement are indicated, giving rise to the Yalingi River shale and sandstone series.

Subsidence followed this uplift, and during this time the limestone beds of the Aitape series were laid down. The succeeding phase introducing volcanic rocks seems to have been very widespread, and took place in Late-Tertiary time.

Following the outpouring of these lavas a considerable amount of uplift is indicated, for the limestones which underlie the volcanic rocks stand at a considerable elevation with reference to the newer coralline limestone assigned to a later period of subsidence.

Probably in Late-Pliocene time (or even Pleistocene) depression followed elevation, coralline limestone being formed in the resultant clear water. In the headwaters of several of the larger rivers sections are exposed up to 70 ft in thickness of muds and gravels which rest unconformably upon Miocene beds. These beds were probably laid down at the same time as the new coral beds. The following uplift in the main divide resulted in the formation of consequent streams flowing northwards to the sea.

It cannot be said that the present coastline shows everywhere signs of recent emergence. In the Matapau area coral beds occur 8 ft above sea-level, at Aitape they form wave-cut benches at half-tide level, while the features presented at Vanimo seem to indicate drowning as the result of the latest movement.

In the St. Anna mission plantation there is a beautifully preserved raised beach which extends between two limestone bluffs. These bluffs mark former headlands and exhibit unmistakable evidence of undercutting by wave action. The fossil beach is about 250 yards from the present shore-line, but it is not more than 6 or 7 ft above mean tide mark. Similar former beach-lines are indicated at Pultulul, Ulan and Tepier plantations. Practically all the coastal streams show deserted channels filled with gravel, and recent land-uplift is indicated by deep dissection and the existence of waterfalls.

At Aitape, however, where our base camp was built, the coralline limestone is practically at sea-level. Pebbles which are found in the coral about 4 ft below the surface have been derived from the volcanic rocks in the adjacent hills. This indicates some degree of subsidence. At the Sissano Lagoon subsidence appears to have taken place within recent historical time.

The Warapu people, invaders from the Wammo district, originally lived about the mouth of the lagoon, but the sea broke through and forced them to find a new home. Dead trees and lines of coconut stumps give some indication of the former drainage. It is difficult to account for the fact that coconut palms on the seaward side of the lagoon have also been submerged, if subsidence has not taken place. The amount

of subsidence indicated is about 6 ft. (maximum), and the date of the event about twenty years ago (Plate III, fig 1)

Paleontology.

The following notes have been supplied by Mr Tom Iredale, of the Australian Museum, locality names in brackets have been added by the writer —

“The specimens submitted included some separate casts, some pieces of limestone, coral rock, and some mudstone samples

“The separate casts were all from 15 miles south of Yakomul, and comprised *Arca* sp, *Circe* sp, *Clementa* sp, *Placina* sp, and apparently *Conus* and *Voluta* spp They were all of similar facies to the recent fauna from the neighbourhood

“The limestone coral rock from Pultulul village shows the impression of an *Arca* valve, very much like one of the recent species Another piece of limestone coral rock (from near Lentre village) shows impressions of species of *Cardium*, very like the recent *Flavum* group

“There are five lots of mudstone, all agreeing in general appearance and showing numerous shell fragments, but solution only gave more, no complete shells dissolving out, and those apparently perfect breaking up, indicating great pressure Of these lots No 5 showed an *Oliva* sp, a *Turritella* sp, and a species of *Mitra* very like recent shells In No 8 a species of *Pyramidella* was distinguishable, in No 31 an *Oliva* like the previously named one could be seen [These came from the beds at Ulau shown on the section on page 84]

“In No 33 the *Turritella* again recurred and a *Pecten* impression was observed [On River near Romu]

“No 25 was a specimen of muddy appearance but harder texture, showing a bivalve which might be a small *Crassatellites* and a gastropod of Cerithioid affinity, but apparently young and broken This lot may be older than the preceding, and the species are not so obviously of recent form [Bliri River, near Maiwetti, south side of main divide] No 29 [from Durali] showed two pieces of corals

“It will be seen that the mud-series do not suggest great age, and probably perfect specimens of the molluscs represented could be reconciled with the Recent fauna The first-named casts may be older, and No 25 much older”

Mr W S Dun, who also examined these fossils, states that they may be considered as either Pliocene or Miocene However, there are other factors which may be considered

Orbitoides limestone occurs at Matapau, about 10 miles east from Ulau, where some of the fossils described above were obtained The age of the former occurrence is Miocene The beds at both these localities are very similar lithologically, and on palaeogeographic grounds cannot be very different in age

Further, the raised coral-beds throughout the Mandated Territory are generally assigned to the Pleistocene (see Evan Stanley's map). The Aitape Series is certainly older than these, and is, therefore, probably Pliocene. The beds of this series are also very similar to beds which occur in other parts of the Territory, to which a Pliocene age has been allotted. The fossiliferous beds in turn are certainly not younger than the Aitape Series.

From this we may conclude (tentatively at least) that the Matapau and Yalingi Beds are generally of the same age, namely Miocene, although they may possibly be referable to different stages within that series.

ECONOMIC GEOLOGY

General

When one has stated that the greater part of the area is covered with Tertiary rocks, it is obvious that there are not likely to be a great number of economic minerals awaiting development.

The altered and igneous rocks of the main divide possibly contain metallic deposits of importance. Apparently no deposits have so far been located in this region, but the recent discovery of gold at Edie Creek, on the Markham River, in an area similarly situated, may encourage prospectors to go farther afield. Prospecting would present very little difficulty, as the dividing range may be reached in no more than two days' journey from Aitape.

There appear to be ample shale and clay available for the manufacture of bricks, tiles, earthenware, and other similar materials. The natives of Tomleo Island have been making pottery for many years from a bright-red clay (derived from the decomposition of andesitic lava) which they obtain from the mainland directly opposite the island.

The coastal limestones have also been used for the manufacture of lime by local mission stations. The natives themselves burn shells and coralline limestones for lime which they chew with the betel-nut.

Petroleum

In the search for oil in a new region it is important to review the factors which affect the occurrence of oil. There are a number of considerations which are essential to the accumulation of oil-pools, but there appears to be no general agreement upon the relative importance to be given to individual factors. The essential conditions may be briefly stated as follows —

- 1 A source from which the oil may have been derived,
- 2 Sedimentary rocks of sufficient thickness, suited lithologically to the storage of oil,
- 3 Suitable geological structures to constitute an oil reservoir,
- 4 Absence of intense metamorphism,
- 5 Suitable water-conditions

In applying these conditions to the geology of the Mandated Territory the absence of detailed information is at once apparent

It seems hardly possible to doubt that there has existed a source from which oil could have been formed. The geological history of the region indicates this. There are also seepages of oil at various places along the Aitape-Madang coast, and small quantities of oil have been obtained by boring at Matapau. Several brine springs giving off the odour of petroleum occur in the Aitape district.*

It seems that the existence of productive oil-fields in the East Indies (Borneo and Ceram, for instance) effectively disposes of the criticism, based on a consideration of climate that a "barren equatorial" belt exists, but there are undoubtedly good reasons, from a consideration of tectonic geology, that oil-fields in such regions may be restricted in area.

It is not likely that oil will be won in the Mandated Territory from rocks older than Tertiary. Tertiary rocks occupy the greater part of the coastal plain and foothills (overlain in places by Pleistocene and Recent rocks) and a considerable part of the inland slopes. Evan Stanley states¹⁰ that "Plio-Miocene foraminiferal mudstones, and carbonaceous sandy mudstones are known nearly 200 miles up the Ramu, whilst further west they occupy valleys in the Eocene and Mesozoic deposits."

From verbal information supplied by Dr. H. I. Jensen, and Messrs. Winters and Lindsay, who have visited different parts of the Aitape, Madang, and Sepik districts, and from personal examination, it is apparent that there is a large extent of Tertiary rocks in the coastal area and in the Sepik and Ramu River valleys. A correlation of this scattered information is very desirable.

The main divide consists of highly folded and altered rocks, and it is understood that igneous and metamorphic rocks occupy portion of the Lower Sepik (verbal information, Dr. Jensen). These areas cannot possibly be regarded as oil-bearing. Surface indications of the occurrence of oil are evident only in areas occupied by Tertiary rocks, which also in other parts of the East Indies are oil-bearing. Probably beds of Miocene age are the only ones which need receive consideration in a preliminary examination.

* Attention may be drawn to the supposed seepage of oil at Lentre (Evan Stanley, "Salient Features of New Guinea," p. 67). Mr. Hanlin, who accompanied me in some of the New Guinea work, visited Lentre, and from verbal information supplied by him it seems likely that the seepage (so called) is not always to be seen, and when apparent appears to be rather a ferric hydroxide film.

* M. G. Mehl, Bull. Sci. Lab. Denison Univ. 1919, vol. 19, pp. 35-63.

¹⁰ Evan Stanley, "Oil Provinces in New Guinea," Proc. Pan-Pacific Science Cong., vol. II, 1923, p. 1249.

Tertiary rocks attain great thickness, and in the Aitape district they certainly exceed any suggested possible minimum for productive oil-fields

Over wide areas, also interbedded shales and sandstones occur, overlain by a considerable thickness of mudstone, and porous "sands" have also been encountered in drilling

From a consideration of palaeogeography it will be seen that the Miocene beds were probably laid down close to an old land mass where a good deal of variation in the physical character of the sediments might be expected, and where sands could accumulate free from the deposition of mud and clay which might close the pore-spaces between the sand-grains

The structural geology indicates that over fairly large areas the Tertiary beds have been but gently folded. From this point of view the beds in the inland slopes are possibly more likely to yield suitable structures, but a greater degree of certainty of obtaining oil would need to exist before prospecting that region in preference to others more accessible

In some places the Tertiary beds have been strongly folded and intruded by igneous rocks of granodioritic type, chiefly in the form of sills. These areas might also be eliminated in a preliminary examination, but as seepages of oil are abundant in such localities important information may be gained as to actual oil horizons

The report of the geologists of the Anglo-Persian Company (as summarised by the late Evan Stanley) is somewhat misleading in its reference to the country inland and west from Aitape. The highly altered and intruded Tertiary beds described by them are not typically developed farther west on the New Guinea coast than Matapau

It is impossible to forecast the water-conditions likely to be met with in drilling. In other parts of the East Indies oil has been won from anticlinal structures, presumably from wet sands, and a similar condition may be expected in New Guinea. On the other hand, verbal information seems to indicate that the beds bored through at Matapau and the lower Sepik have been relatively dry. If this is so, the possibility of the oil occurring on the flanks of anticlines or in synclines should be investigated

In a short review of the conditions such as has been given, many points of interest have not been mentioned, but from what has been written it will probably be admitted that all the factors which need to be considered in an oil field reconnaissance are present on the mainland of New Guinea. The search for oil might well be confined, in the first place, to locating suitable structures in beds of Miocene age, which have not been too highly folded or much intruded by igneous rocks

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(Contains also many other useful references)



Fig 1—Coconut Palm Stumps in the Sissano Lagoon, indicating recent subsidence
The stumps indicate the banks of drowned streams. Brida hills in the distance

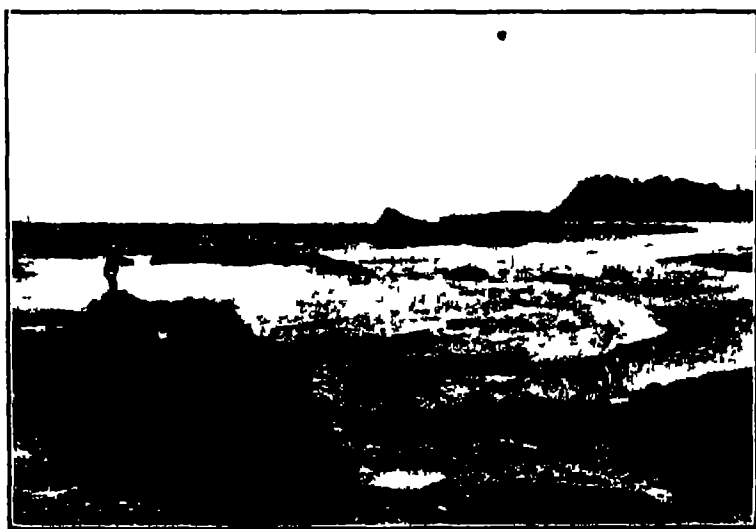


Fig 2—Andesitic Lavas near Tepier Plantation, showing inland (southerly)
dip. Tomleo Island in the distance



Fig. 1—Cliff 70 feet high (of Tertiary Muds and Carbonates) at the junction of the Mu and Yaling Rivers. (Cf. Fig. 1. 81.)



Fig. 2—Miocene Beds (alternating thin beds of Shale and Sandstone) in the Yaling River near Wanung. Southerly dip.



Fig. 1 — Ydingi River at Lupiti showing well-gravel bed and comparatively narrow stream channel. Trees left by recent flood at left.

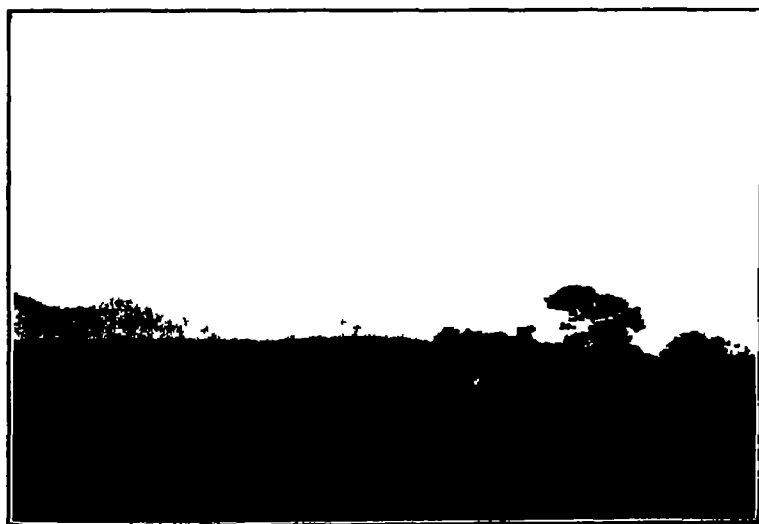


Fig. 2 — Forricelli Mountains, looking south west from Wunigi, showing advanced dissection. Ydingi Valley at left.

Notes on the Breeding Habits of *Culex fatigans* Wied., and its Associated Mosquitoes in Queensland.*

Plates VI and VII

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(Read before the Royal Society of Queensland, 24th September, 1928.)

The vagaries of *Culex fatigans* Wied. (*Culex quinquefasciatus* Say) are particularly noticeable and interesting during such extensive control operations as are at present in vogue in the Greater Brisbane area. This species is the commonest night feeding mosquito in Brisbane. It prefers larger and more permanent areas of polluted waters, when it can get them than might appear to be the case from its domestic habits of breeding in small household receptacles. When *Culex fatigans* gets a firm hold of any locality it is enlightening to follow its methods of making the most of every available scrap of polluted water and the selection of breeding places, both elective and compulsory as the case may be, follows not only as a natural consequence but as an imperative necessity. As a result of this adaptive characteristic the associations with other mosquitoes are most marked the following are frequent —

- 1 *Anopheles (Myzomyia) annulipes* Walker
- 2 *Aedes (Stegomyia) argenteus* Poiret (*A. aegypti* L. Dyar)
(*Stegomyia fasciata* Fabr.)
- 3 *Aedes (Finlaya) notoscriptus* Skuse
- 4 *Lutzia haljazi* Theo (*Culex tigripes* Grandpre)
- 5 *Culex annulirostris* Skuse

and those found less frequently are—

- 6 *Mucidus alternans* Westwood
- 7 *Aedes (Ochlerotatus) vittiger* Skuse
- 8 *Aedes (Ochlerotatus) vigilax* Skuse
- 9 *Aedes (Finlaya) alboannulatus* Macq

ASSOCIATIONS WITH *AEDES ARGENTEUS*

Hitherto the occurrence of this mosquito with *Culex fatigans* has always been regarded as a sign of pollution but, as the number of such associations in this area is on the increase it may be that this occurs owing to the preferential breeding places being reduced in number

* From the Entomological Section of the Department of Health, Brisbane City Council.

When these two mosquitoes are found together in a rainwater tank, a practice of submitting such findings to a closer scrutiny is always made, but only in a few instances was it possible to prove pollution.

During the summer of 1927-28 this association became more frequent still, not merely in unscreened rainwater tanks but in all sorts of water-holding rubbish about human habitations. Discused paint tins in which paint brushes are found soaking, some of which have a lingering smell of turpentine, are a fruitful source of supply. Any characteristic "hay infusion" aroma acts as a lure for *A. argenteus* (Buxton, 3), and *C. fatigans* is frequently found in company with it. The frequent association of *C. fatigans* with *A. argenteus* and *A. notoscriptus* in cemetery jars having this unmistakable "hay aroma" is capable of enormous possibilities (Hamlyn-Harris, 8). H. R. Carter (5) has stated—"We have not found this mosquito (*Aedes (Stegomyia) aegypti*) breeding, in nature, completely, that is, from oviposition to imago, in any collection of water, all the sides of which at the water's edge were of mud." Our own experiences correspond with this.

Knab once found *Aedes argenteus* in a small waterhole in a street in a Central American town, but Carter explained this on the supposition that the puddle was formed of water poured from some domestic vessel. Quite one of the most important associations which has come to our notice during recent years is that of the occurrence of *Aedes argenteus* in an artificial pool of water lying on the ground under a house in the city area with *C. fatigans* associated with it (pH 6.4). This occurrence, so contrary to our usual findings, was at first difficult of explanation, but on further investigation it transpired that *A. argenteus* was breeding in a section of the roof guttering of the house, and that after rain the overflow pipe carried the water directly into a small drain. At some time or other the children of the house had connected this drain with one of their own making, which led the water from one side of the house to another to a pool made formidable enough to enable them to sail their small craft. Soon after, the house was closed up for the Christmas vacation and the pool was left entirely undisturbed until found.

As far as our experience goes, such a breeding place has never been recorded for *Aedes argenteus* in Queensland before, though there are two instances on record of this mosquito breeding in the first place in a flower pot, and in the second in a tin containing ferns both of which had during the rainy season become filled with water the soil having set did not allow the water to percolate through, and in each case there was about half an inch of water above the coarse particles in the receptacle, most of the finer soil having been washed away. Both these breeding places were quite close to the house and were situated among dense foliage in a bush house.

ASSOCIATIONS WITH *LUTZIA HALIFAXI*

This "cannibalistic" mosquito occurs in Brisbane only during the summer season, though Bancroft says that it is to be found all the year

round, this is not so in our experience. We find it to be essentially a warm-weather mosquito occurring only during the hottest months in the year. It was particularly plentiful during the first three months of 1928, and was seldom found unassociated. Its association with *C. fatigans* was the more usual, though it occurs also in company with *A. annulipes* and *A. notoscriptus* in such places as freshly filled kerosene tins of water left lying about the garden, places which after rain incidentally contain numbers of Chironomid larvæ. This kind of association seems unusual, for *Lutzia halifaxi* is for the most part a foul-water breeder like *C. fatigans*. *Lutzia halifaxi*, however, becomes an easy prey to over-pollution and it is astonishing how quickly larvae of this species die when kept in artificial receptacles not properly aerated. *Lutzia halifaxi* associates with *A. argenteus* in comparatively clean water, in horse-troughs, and such-like places.

ASSOCIATIONS WITH *ANOPHELES ANNULIPES*

Associations with *Anopheles annulipes* occur mostly in vessels containing clean water. Household rubbish of all kinds recently filled by rain will breed such an association. Such receptacles, either artificial or otherwise particularly rich in Infusoria and Algae, are usually avoided. As is to be expected, such an association is not confined to vessels, but occurs equally well in waterholes in which a suitable food supply occurs. *C. fatigans* will not however, associate with *A. annulipes* unless pollution is present even if only to a slight degree, and the hydrogen ion concentration of the water in such a case is found to be in the region of neutrality, or on the acid side of neutrality. This is rather significant in view of the fact that all the highly polluted areas of Brisbane yield a pH usually well over 8.0, but *A. annulipes* does not apparently associate with *C. fatigans* under such conditions.

ASSOCIATIONS WITH *CULEX ANNULIROSTRIS* AND *AEDEN ALBOANNULATUS*

These two mosquitoes have frequently been found together, and therefore, if under certain favourable conditions *C. fatigans* by reason of its ubiquity is found associated with them, it should occasion no surprise. These mosquitoes breed in fresh waterholes and swamps, sometimes in prodigious numbers with *A. annulipes* along the edges of the same. Such swamps are subject to degrees of pollution on account of cattle and horses, the pH of the water is usually found to be in the region of 6.5. The occasions on which such associations occur are comparatively rare and are dependent entirely on local conditions, it being during times of drought that such take place. Interesting cyclic variations occur frequently. One chosen from among many, considered worthy of note, occurred during the winter months of 1926.

(1) *C. annulirostris*, (2) *A. alboannulatus*, and (3) *Anopheles annulipes* were found associated together in a large waterhole which formed a portion of a natural watercourse at St Lucia. This waterhole was filled with *Nitella myriotricha* Kutz, a great deal of which lay on

the surface of the water and was completely covered with a ferric oxide deposit, the pH hardly varied at all, but remained in the region of 6.6 all the time that the place was under observation. During a spell of dry weather in the late summer *Nitella myrtilloides* still subsisted but in smaller quantities, and only *Anopheles annulipes* remained of the three original mosquitoes. *C. fatigans* selected it in the meanwhile on account of its elective breeding places becoming dried up.

ASSOCIATION WITH *CULEX ANNULIROSTRIS* AND *ANOPHELES ANNULIPES*

The question of alternative breeding in pools and larger waterholes is rather interesting, and produces sometimes unlooked-for associations. During the last twelve months a number of such waterholes were selected for regular observations, inspections were made once a month and the results noted. Sylvan mosquitoes mostly bred in these waters but the presence of *C. fatigans* always coincided with temporary pollution, and the commonest associated mosquitoes were invariably *A. annulipes* and *C. annulirostris*. In many of these waterholes ideal conditions exist as long as the pH remains in the region of 7, various aquatic plants are found, and the presence of large numbers of predaceous insect forms is doubtless responsible for the fact that for long periods of time mosquito larvae are extremely scarce.

In one permanent salt waterhole, which was covered only at high tides but which dried up periodically, an interesting alternation of *Aedes regularis* and *Aedes alboannulatus* was noticed, the association of such forms with *C. fatigans* is not unknown but is of very rare occurrence according to the preponderance of either salt, brackish, or fresh water. When the volume of water in these waterholes is greatly increased by heavy rains, breeding seems to be temporarily arrested, and then *C. annulirostris* and *A. annulipes* seem to be the first mosquitoes to take possession and continue to flourish until pollution becomes too pronounced, and then *C. fatigans* holds undivided sway.

C. FATIGANS AND BRACKISH WATER

It is only very rarely that this mosquito is found breeding in brackish water, and when it is, it is probably accidental. *C. fatigans* occurs sometimes in polluted tidal creeks after heavy rains, but these mosquitoes disappear after exceptionally high tides. An association of *C. fatigans* with *Mucidus alternans* does not occur very often. Along the coast and within a few feet of the sea *A. vittiger* and *M. alternans* associate frequently in comparatively fresh water, but though *C. fatigans* has been taken in association with each individually it has not so far been taken in the company of both. *A. vittiger* usually prefers an acid water (pH 6.4 or thereabouts), but such is not selected preferentially by *C. fatigans*. Cyclic alternations are bound to occur and are comparatively frequent in Southern Queensland. Some interesting instances are shown in Figs 1-5 illustrating this paper.

HYDROGEN ION CONCENTRATION

Although at times *C. fatigans* behaves as an acidophile, in our experience it more frequently prefers alkalinity. Its principal breeding places as a rule have a pH ranging from 7.4 to 8.6, and one is inclined to believe that it is in this state of concentration that the food suited to the species is most likely to occur. Water contained in drains, cemented sewers, gully-traps, and other polluted waters from household refuse generally have such a pH. Whether breeding mosquitoes or not they contain plentiful supplies of organic waste and are, almost without exception, highly alkaline. If, by experimentation, the pH is swung to an acidity in the region of 5.0, the death of the larvæ and pupæ soon follows.

In the laboratory, feeding the larvæ on bananas proved a fairly successful method of swinging the pH from alkalinity to acidity. At first the larvæ thrived, but only for a short time, for the development and subsequent action of decomposition products followed soon after. In one experiment in which distilled water was used the larvæ died in a pH 5.0 and in another in tap water in a pH of 5.4.

HIGH MORTALITY AMONG LARVAL AND PUPAL FORMS

Larvæ of *C. fatigans* are particularly prone to suffer from a type of "intoxication" induced by the decay of food present, to say nothing of the "corpses" of their companions upon which they feed. Such "intoxication" is always more in evidence in artificial containers. During the hot summer months the mortality of thousands of larvæ and pupæ is particularly noticeable in some of our Brisbane cemeteries where the hot sun beats down on totally unprotected graves. Such water is usually alkaline. It is probable, too, that large quantities of CO_2 are evolved from the decaying matter contained in the vases, and, from the general behaviour of the larvæ and pupæ in particular, slow poisoning of some sort is apparent. The death of all pupæ in such containers is particularly noticeable. CO_2 is capable of acting as such a narcotic poison. Retardation of development is common under laboratory conditions. Poisonous excretory matter might contribute to such a result (see Williamson, 11).

The abnormality which occurs during the summer months, in cemeteries, suggests that larvæ and pupæ are dependent upon both atmospheric and dissolved air. This particular phase is worthy of further investigation.

When natural food does not suffice there is little doubt that *C. fatigans* becomes cannibalistic. In carefully prepared experiments where the water, brought from the cemeteries, had been filtered and deprived of all visible food material and then provided with large numbers of egg-rafts, enormous numbers of young larvæ were produced, their growth being prodigious, and many of the younger larvæ were devoured. The large numbers of larvæ sacrificed in this way seemed out of all proportion to the numbers surviving. Surviving larvæ fed under

these conditions develop rapidly, and instances are on record of pupation taking place soon after the sixth day in consequence, conditions of temperature and humidity, of course, being exceptionally favourable

CEMETERIES AND *C. FATIGANS*

During a survey of the following three cemeteries made in mid-summer 1927-28, the hereunder mentioned conditions were found to exist —

Nudgee Cemetery

Graves Examined	Total Number of Vessels	Vessels with Water	Vessels found breeding	Percentage of Graves breeding	Percentage with Dead Larvæ	Types of Mosquitoes found	pH Range
127	420	340	96	75.5	40.2	<i>C. fatigans</i> 84.4% <i>A. notoscriptus</i> 2.9% <i>A. annulipes</i> 0.9% Associations of <i>C. fatigans</i> and <i>A. notoscriptus</i> 12.4%	6.6-8.6

This cemetery, though situated in the Greater Brisbane area, is right outside the city proper in an eight-mile radius and is, therefore, subject to sylvan conditions, and on account of its comparative isolation is not breeding the essentially domestic *A. argenteus*.

The enormous number of egg-rafts laid in jardinière of a half-gallon capacity was very noticeable, various lots of 50, 25, 18, and so forth laid in one vessel were quite common. Such jardinières are great favourites and are especially selected, of 71 taken on these graves alone, 44 were found breeding *C. fatigans*.

Nundah Cemetery

Graves Examined	Total Number of Vessels	Vessels with Water	Vessels found breeding	Percentage of Graves breeding	Percentage with Dead Larvæ	Types of Mosquitoes found	pH Range
150	493	430	94	62.6	30.4	<i>C. fatigans</i> 97.4% <i>A. argenteus</i> 0.7% Associations of <i>C. fatigans</i> and <i>A. argenteus</i> 1.9%	7.4-8.0

Nundah Cemetery, previously known as German Station, is situated in the four-mile radius. It is isolated on high ground surrounded on three sides by hyacinth-covered swamps, doubtless partially polluted from the cemetery itself. This explains to some extent the absence of associations of *A. notoscriptus*, &c., and the presence of *C. fatigans* as the dominant mosquito, the few examples of *A. argenteus* could be definitely traced to graves in close proximity to the caretaker's lodge. The largest number of vessels on any one grave numbered 28, 65 per cent of these

were breeding *C. fatigans*, two large jardinières were included in this lot, one more exposed than the other had 45 egg-rafts in addition to numbers of larvæ, &c, in all stages, and the other jardinière exposed to the full heat of the sun contained putrid water and hundreds of dead larvæ, and especially large numbers of dead pupæ.

Lutwyche Cemetery

Graves Examined	Total Number of Vessels	Vessels with Water	Vessels found breeding	Percentage of Graves breeding	Percentage with Dead Larvæ	Type of Mosquitoes found	pH Range
100	404	310	67	67	13.0	<i>C. fatigans</i>	6.6-7.8

Lutwyche Cemetery is on the main Gympie road in the four-mile radius. No mosquitoes other than *C. fatigans* were taken here. The proximity of this cemetery to four tanneries with the subsequent pollution of natural watercourses, and the flooding of the whole neighbourhood with *C. fatigans* in consequence (prior to the existence of mosquito work in this area) may be advanced as a possible explanation.

TECHNIQUE EMPLOYED

It may be advisable to add a few lines with regard to the technique employed in the identification of larvæ bred in cemetery jars. When jars are fully supplied with larvæ it is naturally somewhat difficult to avoid missing one here and there, and, in order to make it possible to keep all under observation, a method of pouring the contents of the jar into a 1,000 cc measuring glass and filling up the same with water was used, by this means the water becomes more transparent and the larvæ are made to pass to and fro under observation, whilst a long pipette introduced will bring any coveted specimen to the surface for further examination. If the water is very dark and muddy as frequently happens, no larvæ may be visible, and in such a case it will be necessary to decant only small quantities of the fluid at a time, but with patience accurate results can be obtained.

C. FATIGANS AS A TREE-CAVITY BREEDER

Although *C. fatigans* is found breeding in tree cavities here and there, it is evidently not a tree-breeding species, nor does it occur in sufficient quantities in trees to make it a serious menace in mosquito control. Associated with *C. fatigans* in such cavities in midsummer we find larvæ of Syrphid flies, Chironomids, and *Culeicoides* sp., &c, the pH of such water being usually in the region of 6.0-6.5.

C. FATIGANS UNDER LABORATORY CONDITIONS

In the laboratory, *C. fatigans* will oviposit at some time or other, on any available water. During the course of the last eighteen months,

various jars containing Charophyta have been under constant observation, the following species were used, being easily procurable —

- (1) *Nitella diffusa* Braun,
- (2) *Nitella cristata* Braun,
- (3) *Nitella myriotracha* Kutz,
- (4) *Nitella phauloteles* Groves

These yielded a constant supply of egg-rafts available for experimental work as desired (See Hamlyn-Harris, 9)

OBSERVATIONS EGGS LAID IN JARS CONTAINING THE AQUATIC PLANT, NITELLA SP *

Observation No 1—

Egg Raft Laid	Number of Larvae Produced	Total Number Matured	Number of Females	Number of Males	Final Emergence
30-9-26 (Spring)	256	128	82	46	29-11-26

Observation No 2—

Egg Raft Laid	Number of Larvae Produced	Total Number Matured	Number of Females	Number of Males	Final Emergence
10-5-26 (Autumn) Hatched on 11-6-26	256	170 3 larvae, 8 pupae died, leaving a total of 75 unaccounted for	84	86	28-6-26

In *Observation No 1* a total loss of 131 larvae was registered, spread over a period of two months. Of the remaining 128, 34 males and 37 females matured during the first month (September). The only food supplied in this instance consisted of dried blood given as required.

In *Observation No 2*, during the whole of the seven weeks the water remained unchanged but was added to when necessary, the pH remaining in the region of 8.6. Agar was used as food supplemented by blood preserved in 1/560 formalin. During the whole period the temperature ranged from 64 to 73 deg F.

Rates of development of larvae during midwinter—

		Temperature Deg F
Raft of 256 eggs laid	May 10	73
Eggs hatched out	May 11	72
Appearance of 1st pupa	May 24	67
Emergence of 3 imagoes, all males	May 27	67
Emergence of 3 imagoes, 9 males	May 28	65

* There seems no reason to differentiate between the various species since they all without exception behave similarly, though *A. argenteus* is more persistent in selecting them than is *C. fatigans*.

		Temperature. Deg F
Emergence of 3 imagos, 6 males	May 29	65
Emergence of 1st female	May 29	65
Emergence of 17 males and 6 females	May 31	

Making a total of 35 males as against 7 females, 42 in all, during the first three weeks

The preponderance of males over females continued until about the 20th June, after which date only females emerged. The temperature was taken at 9 30 a.m. each day, and during this period never registered less than 65 and not more than 68 deg F. Whilst being fed on Agar all larvæ were of an opaque whiteness, which, however, vanished when fed on blood. There was a period of exceptionally slow growth about the 9th June, when for seven days no males but only five females matured, and what appeared to be a kind of intoxication seemed to have set in, a state of things rectified, however, by the addition of fresh Agar and blood.

Observation No 3—Six individual egg-rafts taken at random yielded the following results—

Egg Raft Laid	Number of Larvæ Hatched	Number of Pupæ Matured	Percentage Maturing
1 28-9-26	75	No record	
2 28-9-26	259	140	54 06
3 28-9-26	227	No record	
4 31-10-26	156	19	12 00
5 18-11-27	328	241	73 40
6 5-12-27	295	198	67 40

Unfertile Eggs—In addition to the above records there is evidence that some egg-rafts are laid which fail to produce larvæ. It is impossible at this stage to give any reason for this, but the idea that mosquitoes can lay unfertile eggs has now become a firm conviction, and further research is highly desirable. Dr W. Rudolfs, of New Jersey, has confirmed this, and in a letter to the author makes the following statement—

“Last summer we were feeding larvæ of the house mosquito more or less pure cultures of Protozoa and Algæ. During this study of food requirements, our Zoologist noted that in a number of instances mosquitoes which hatched from these larvæ laid unfertile eggs. We have no conception at present what the cause is, but since it was noticed several times we made a record of it and are planning to follow it up some time in the near future.”

Further evidence as to the non-fertility of eggs is produced by Brug (2).

SEPTIC TANKS

It is here necessary to draw attention to septic tanks being actual and potential breeding places of '*C. fatigans*'. It has been known for a long time that under favourable conditions such tanks may afford ideal breeding places. Our records point to about 50 per cent of the tanks installed in this area breeding, and owing to this it has become imperative to insist on the screening of every pipe connected with the exterior of the tank as a means of permanent control. This condition is brought about either by the breaking of the "scum" or by the presence of a second chamber in which a "scum" is not formed. Septic tanks are sometimes selected during the process of construction, and, when sealed with larvæ in full possession, do not apparently produce a "scum" and in consequence become a special menace in mosquito control. This type of breeding place obviously must be taken into account in any mosquito control measures adopted in centres of population.

C. FATIGANS IN HUMAN FÆCES

Human fæces, although providing adequate food material for the larvæ of this species, is as a rule too crude a material for such breeding places to become selective. Several instances of *C. fatigans* breeding in such material have been observed at seaside resorts in the contents of sanitary pans, diluted by rain, left standing out of doors.

C. FATIGANS IN RELATION TO TANNERIES

Watercourses polluted by tanneries are favourable breeding places of *C. fatigans*. When the waste is first released, it is extremely acid and mosquitoes will not breed in it, but gradually as the dark coffee-coloured liquid gets further away and becomes alkaline it is extremely attractive to '*C. fatigans*', but no associations occur until the pollution becomes considerably less pronounced, when *A. annulipes* and '*C. annulirostris*' are found in association. Surveys of tanneries reveal numerous breeding places, and it is unnecessary in a paper of this nature to enumerate all of them, but one or two are here referred to as demanding special vigilance.

(1) *Soak-water*—It is in this water that the hides are washed before going into the lime liquors, and if allowed to remain standing after the hides have passed through it becomes an important breeding place. If, however, such pits are kept regularly under observation, they can be made to act as excellent lures, and many larvæ can be eliminated by such means.

(2) *De-liming solution containing boracic acid*—The strength of this solution is usually about 0.5 per cent. After use the boracic acid is changed to calcium borate by the lime in the hides. These solutions, if allowed to stand, are not in any way repulsive to '*C. fatigans*'.

(3) *Lime Pits*—Lime pits in actual practice are capable of breeding millions of mosquitoes. It was Borel (1) who said that a coating of white lime prevents the deposition of mosquito eggs in water containers.

Our experience is that, in a saturated solution containing 0.192 grams of lime per litre at 15 deg C, mosquitoes will not lay their eggs as long as CaCO_3 , by the absorption of CO_2 from the atmosphere, forms a solid and insoluble film on its surface. As the solution becomes weaker, owing to the film being broken by wind or other causes, *C. fatigans* is given the opportunity it requires, and breeding is apt to go on rapidly. Unused lime pits are therefore a serious menace, and demand constant control.

(4) *Tan Liquor Pits*—The pH of the liquor in the pits (due to lactic and acetic acids) varies between 3.3-4.5, according to the tanning material used. As long as this hydrogen ion concentration is maintained no mosquitoes will lay their eggs on it. The pH of the weaker liquors in use is somewhere in the region of 5.2-5.8, but even this is not selected. What the real significance of the film of yeast which forms on the surface of tan liquors may be, and whether it has any deterrent effects in itself apart from the acidity of the liquor, is difficult to determine. All tanning matter in solution tends to decompose or become precipitated. Decomposition is greatest at the surface, on account of the greater warmth and the presence of oxygen. If left standing long enough, the surface of such liquor will become so watery that *C. fatigans* will select it unremittently. Breeding may be controlled by covering the surface with a heavy layer of a volatile oil such as kerosene, with the following results—(1) Arrest of decomposition (2) prevention of mosquito-breeding, (3) no injury to tanning liquor.

SUMMARY AND CONCLUSIONS

1 *C. fatigans* is found associated with no less than nine different species of mosquitoes in the Greater Brisbane area. The association is dependent, to a very large extent, upon the state of the water at the time of selection.

2 There exist cyclic variations in the associations referred to, due to rain and atmospheric conditions in which temperature and humidity play no small part. These cyclic alternations must not be regarded as incapable of variation but rather as a sign of interesting possibilities.

3 The study of hydrogen ion concentration, within certain limits, of waters selected for breeding purposes, does not throw any light upon the reason for selection, but only serves as an indication of the type of water preferred by certain kinds of foodstuffs or organisms or aquatic vegetation, as the case may be.

4 There is considerable mortality among the developmental stages of *C. fatigans* at all times, but especially during hot summer weather. It is surmised that this is due either to a species of intoxication or narcotic poisoning, or to the toxic nature of the decomposition products, especially induced by a high temperature.

5 Investigations into the breeding of mosquitoes in the Brisbane cemeteries lead to the belief that *C. fatigans* and *Aedes notoscriptus* choose the artificial receptacles on graves more so than other mosquitoes,

and use them to the full extent of their power *C fatigans* holds undivided sway in some cemeteries, *Aedes argenteus* choosing vessels near human habitations for preference

6 *C fatigans* is not by nature a tree-cavity breeder, but might become so as elective breeding places become scarce

7 *Mucidus alternans*, a cannibalistic species, and *Aedes (O) vigilax*, usually associated with it, are both by nature saltwater marsh mosquitoes, but their presence at certain times of the year in large numbers in fresh waterholes is significant and highly undesirable. When these occur in association with *Aedes vittiger* it is interesting to note that, in spite of the fact that the larvæ of *Aedes vittiger* are predaceous, they will, nevertheless, avoid any intercourse with the other two mosquitoes even if found in the same water, and will select a secluded spot where they are less liable to attack. It is surmised that *Mucidus alternans* and *Aedes vigilax* select fresh water only from compulsion

8 Further observations show that the Charophyta referred to in this article and comparatively common around Brisbane do not thrive in pollution, and hence, when mosquito larvæ exist in conjunction with *Nitella* in the field, it is usually in the company of *A annulipes* and with other sylvan mosquitoes rather than with *C fatigans*

9 Under laboratory conditions, however, it is quite a common thing for *C fatigans* to lay egg-rafts upon *Nitella* water, though *A argenteus* selectively seems to do so more frequently

10 As is to be expected, the size of the egg-rafts of *C fatigans* is entirely dependent upon the state of maturity of the female responsible for them. Experiments go to show that males mature first. It would appear that the presence of food is not the main determining factor in the rate of development. It is surmised that the nature of the water itself, in its ability to preserve food supplies in a perfect state without any adverse decomposition products, is of more importance than has been thought likely, other determining factors such as temperature, humidity, &c, being only contributory. In experimentations in the field, as well as under laboratory conditions, it was found that the vitality of larvæ was in direct proportion to the concentration of decomposition products of the water contents

11 Though the presence of food, therefore, seems to be the determining factor in the selection of its breeding places, the number and quality of the decomposition products in the water may be said to be the main determining factors with regard to the measure of retardation in development of *C fatigans*

12 Under laboratory conditions eggs sometimes fail to produce larvæ, and it is therefore naturally surmised that unfertile females, even though possibly fed on blood, produce unfertile eggs

13 The possibilities of the septic tank as a breeding ground for *C fatigans* must be recognised in any active anti-mosquito campaign,

CYCLIC ALTERNATIONS



CLEARING OVER NATURAL WATERCOURSE (BRISBANE)

Fig. 1—Breeding place of *Aedes (O.) vittiger* in February 1927. A month later *Eulisia halifera* reigned supreme here. With the advent of winter this species was displaced by *C. fatigans*.



NATURAL STORM WATER CHANNEL (BRISBANE)

Fig. 2—Breeding ground of *C. annulirostris* and *Anopheles annulipes* in association, both these mosquitoes will breed here most of the year round when pollution is of the slightest and the watercourse does not dry up. *C. fatigans* breeds here with increased pollution.

CYCLIC ALTERNATIONS



Fig. 3. Breeding ground of *C. annulirostris* and *A. (E.) albomaculatus* in association during the winter of 1926 in company with *Nitella diffusa* when the pH stood at 6.8 after a long period of rainy weather. A year later pollution became more and more apparent *Nitella diffusa* disappeared and *C. fatigans* displaced the other two mosquitoes (pH 6.1) (St. Lucia Brisbane area).



Fig. 4. Typical fresh water breeding place of *A. (O.) vittiger* at the entrance to the Brisbane River sometimes submerged by very high tide. *Mucidus alternans* and *A. (O.) vittiger* were found here in association with the above in large numbers (Lytton Brisbane area).



Fig. 5. An old trench 2 feet deep making a typical breeding place for several pest mosquitoes of the *Vittiger* type but not selected by *C. fatigans* though this mosquito breeds freely in the film which float on its surface. *C. fatigans* avoids the water itself.

and the screening of the pipes connected with the exterior made an imperative necessity

14 Brisbane possesses a number of tanneries which, in the ordinary course of events, produce pollution responsible for enormous numbers of *C fatigans*.

15 Soak-water, de-liming solutions, and lime-pits are also capable of breeding prodigious numbers, though in the latter a film of CaCO_3 will, so long as it subsists, debar mosquitoes from breeding in them

16 Tan liquor pits are far too acid for selection, but, as the liquor weakens and decomposition of the surface proceeds, *C fatigans* may select it preferentially

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Stress Transmission in Frictional-Cohesive Material.

By R W H HAWKEN, B A, M E

(Read before the Royal Society of Queensland, 24th September, 1928)

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SUMMARY

This is an inquiry into the question of stress transmission in material other than fluids. Fluid pressure is taken as the fundamental law, and the change in stress throughout the material, arising from potential frictional and cohesive resistance to shear, separately and conjointly, are expounded.

The author's method goes on the assumption that the cohesive resistance is independent of previously existing stress equilibrium for non-cohesive material. Consequently, in the computation, cohesion is treated as an independent shear introduced as a maximum on a plane with corresponding shears on all other planes. The plane on which the shear "c" is introduced will be the 'Critical Plane of Equilibrium'.

In the ellipse of stress deduced, the active shear on the critical plane is equilibrated by the potential resistance to shear due to both frictional and cohesive resistance

The outstanding factor of the analysis here set out is that the principal planes for frictional-cohesive material differ necessarily in direction from those for the same loading, presuming no cohesion

In the author's view, the theories of Rankine ("Earth Pressure"), of Navier ("Failure in Compression"), and Guest, as to Failure by Shear, are special limiting cases. Those of Scheffler ("Unsupported Banks"), Ketchum ("Trench Cutting"), Bell ("Pressure in Clay"), and any "Straight Line Wedge" theory for "Cohesive Material," have the same basic error, namely, that a limiting condition, impossible practically, is assumed as existing for the general case

The author's view being at variance with accepted theories, the reasons are discussed from several aspects and illustrated by examples, theoretic and practical

INTRODUCTION

Consequent to his investigations of the theory of the pressure of non-fluid material, such as sand or soil, on a supporting wall, the author came to the conclusion that, for the purpose of computing stress transmission, any material may be regarded primarily as a fluid

Dry sand has frictional resistance to shear. Soils have some tensile strength or cohesion in addition to frictional resistance and finally, "solids" in which cohesion predominates may, or may not, have frictional resistance

The behaviour of such materials can be deduced from the influences of friction and cohesion, separately and conjointly, on a supposititious fluid of the same dimensions and loading

The subject is fundamental to any treatment of the strength of materials, and has attracted the attention* of mathematicians and physicists as well as engineers

The many authorities differ in regard to assumptions, and more still as to conclusions. At the risk of repetition, an attempt will be made to correlate and amend existing theories in the light of the author's generalisation of the problem

DEFINITIONS AND NOTATION

Frictional Resistance is potential resistance to movement in the direction at right angles to, and due to, applied normal stress

[*Note* The law assumed is that tangential resistance varies directly as the normal stress, but the general reasoning would not be affected if the resistance were assumed to vary as some power of the normal]

* See "History of the Development of Lateral Earth Pressure Theory," by Dr Jacob Feld, Proc Brooklyn Engineers' Club, July 1928, pp 61-104. This able review does not discuss the important investigation of A. L. Bell expounded in the present paper

Cohesive Resistance is potential resistance to movement independent of the normal stress

[*Note* Cohesive Resistance as defined implies equal resistance to tension and compression, but this resistance to tension and compression is not the "Tensile Strength" nor "Compressive Strength" as usually understood, for reasons to be explained]

Principal Planes are two planes at right angles to each other on which pure normal stresses exist, that is, on which there is no shear

The Critical Plane of Equilibrium ("Critical Plane") is the plane on which incipient movement would take place It may become also "The Plane of Rupture"

[*Note* All planes are infinitesimal, that is to say, lengths are considered small enough to justify the assumption of uniformity of conditions over the length]

The Notation used is as follows —

c is the value of cohesion presumed constant, that is, resistance to movement $= n' \tan \phi + c$,

n is normal stress on a plane,

s is shear stress on the same plane as " n " exists,

β is the varying angle added to the angle of friction by cohesion giving a "virtual" angle of friction $(\phi + \beta)$,

γ is the complement of $\phi = \pi/2 - \phi$,

θ is the angle made by any plane with the principal plane,

ϕ is the angle of friction, that is, frictional resistance to movement $= n \tan \phi$,

ρ is the angle made by the Critical Plane with the Principal Plane

A suffix "₀" is attached when cohesion is not acting, that is for frictional non-cohesive material A dash is added when cohesion is acting as well as friction, that is, in frictional-cohesive material A suffix "₁" is added for cohesive non-frictional material

Thus p_0 , q_0 are principal stresses presuming no cohesion, and p' , q' are principal stresses presuming cohesion and friction n' is the normal in an ellipse (p' , q') Similarly with other symbols

FLUIDS, FRICTION, SHEAR, AND COHESION

A short review of general principles, as interpreted or developed by the author, will be given as follows —

Fluid

The primary experimental law of static equilibrium is "fluid pressure," that is, that any pressure applied in any direction transmits, or has equilibrating stresses, in every direction, of the same intensity (1) That is to say, the "ellipse of stress" is a circle and the principal planes are indeterminate,* or, in other words, all planes are principal planes .. (2)

* Actually the direction of the applied load if purely normal (o f gravity) is one principal stress, and, on any other planes, the stress is infinitesimally less

Friction and Shear

The next step is to assume the material to have frictional resistance to shear. Then the equilibrating principal stress is the least possible to preserve equilibrium.

For the limiting conditions of equilibrium on a certain plane (called the "Critical Plane of Equilibrium"* by the author), the principal axis makes a known angle with the Critical Plane (3)

In symbols—

If ϕ is the angle of friction $= \pi/2 - \gamma$, then the principal axis makes an angle $\pi/4 - \phi/2$ or $\gamma/2$ with the critical plane. (4)

This relation has been deduced† from a consideration of the limiting relation between shear or tangential stress " s ," and the passive resistance to shear $n \tan \phi$, due to normal stress " n ," namely—

that $s = n \tan \phi$ on the critical plane ..(5)

Also, as such plane is unique—

if θ is the angle made by a plane with the principal plane,

$$\frac{ds}{d\theta} = \frac{d}{d\theta} (n \tan \phi) \quad \dots (6)$$

Or, graphically—

The curve of $n \tan \phi$ touches the curve of " s " for the value of θ , deduced from (5) and (6) and given by (4) ..(7)

So far as frictional resistance alone is concerned, the state of affairs is—

If the direction of the critical plane is known or fixed, then the direction of the principal stress is also known, that is, is given by (4) (8)

Or conversely—

If the direction of the principal stress is known, then the direction of the critical plane is known (9)

In symbols and quantitatively—

If p_0 and q_0 are the principal stresses for non-cohesive material, and if ρ_0 is the angle between the critical plane and principal plane, it has been shown that—

$$q_0 = p_0 \tan^2 \gamma/2 \quad (i)$$

$$\text{and } \rho_0 = \gamma/2 \quad (ii)$$

also on the critical plane the resultant intensity makes an angle ϕ with the normal, and the vector components of the resultant are at right angles to each other (iii) .. (10)

* The term "Plane of Rupture" is inappropriate when speaking of conditions of equilibrium. It might be called "The Plane of Incipient Rupture."

† The original deduction by Rankine follows different lines, see (10) below, which summarises Rankine's method.

In words, (10) may be expressed as follows —

In a frictional material (presumed non-cohesive), a principal stress " p_0 " on one plane transmits, or is equilibrated by, a stress " q_0 " on the plane normal to the first, and stresses in other directions according to the ellipse of stress, and the Critical Plane, or plane on which the limiting conditions of equilibrium exist, that is, on which incipient failure occurs, makes an angle $\gamma/2$ with the direction of the Principal Plane (11)

Cohesion

In general terms —

A normal stress on one plane must be accompanied by a concomitant reaction on the plane at right angles to that in which the load is applied. In non-cohesive material such reaction is positive. In frictional-cohesive material, for the cohesive resistance to be fully developed it may be positive, zero, or negative, according to the cohesion functioning (12)

THE ELLIPSE OF STRESS

Any condition of statical stress equilibrium, however complicated apparently, actually consists of—

- (a) Normal stresses of equal intensity, F say, and the same sign on two planes at right angles, together with—
- (b) Normal stresses of equal intensity, S say, and of opposite sign on the same two planes (13)

The Planes mentioned in (13) are the Principal Planes, on any other plane the resultant stress is the vector addition of F normal and S inclined at an angle 2θ with the normal. The resultants are the polar co ordinates of the ellipse of stress* (13A)

That is—

- (a) Fluid Pressure F in all directions,
- (b) Normal Stress of equal intensity S , of opposite signs on two planes of definite direction, that is, shear of the same intensity S on two planes making angles of 45° with the definite direction mentioned (14)

That is—

- (a) Fluid Pressure F ,
- (b) Shear S on a plane in a definite direction (15)

Result (15) shows that the *direction* of the principal planes is determined by the direction of, and amount of, shear. The normal fluid stresses have no influence on the *direction* of principal planes, they contribute to intensities only on such principal planes, as they do to the normal intensities on all planes. (16)

Again, from (13) and the Ellipse of Stress—

$$\begin{aligned} F + S &= \text{one principal stress, } p \\ F - S &= \text{other principal stress, } q \end{aligned} \quad (17)$$

* A detailed exposition is given in "Critical Planes," Trans. I E, Aust., 1928.

The effect of cohesion has been examined in the author's paper "Critical Planes in Cohesive Material"* from the point of view of finding the position of the principal planes for frictional-cohesive material, relative to the principal planes for no-cohesion

The standard analyses assume the principal plane to be the same in both cases, but the author maintains that this assumption is wrong, and will endeavour in what follows to expound his views

FRICTIONAL NON COHESIVE MATERIAL

Rankine Theory

As in a fluid, the material must be supported laterally at any depth and at every depth, also, q_0 is always less than p_0 and approaches zero for non cohesive material when γ/λ approaches 0, that is, $\phi = 90^\circ$

A non cohesive material has some 'angle of friction' intermediate between the limits $\phi = 0$ and $\phi = 90^\circ$

The theoretic deduction obviously is for a regular material, and the ϕ assumed and consequential slope of the critical curve, is for so much of the material over which conditions may be reasonably assumed constant†

(18)

Under self-loading conditions, the extraneous stress is gravity acting vertically, consequently, for gravity as the load, the principal stress may be assumed vertical,‡ the other corresponding principal stress is horizontal, that is, normal to the applied stress

(19)

This conclusion is, apparently, not borne out by experiments which record an inclined stress on the vertical wall. No method has as yet been applied extensively to measure static pressure in the form suited to check the deductions experimentally. For this purpose, a series of "pressure gauges" to record vertical, horizontal, or inclined intensities, each over a small area at various points, would be required

To the author it seems that next the wall, say in a bin, movement attempts to take place along the face due to the straining or horizontal

* Proc Inst of Engineers, Aust., 1928

† Various portions or various grains of irregular shape may cause secondary bends or irregularities on a smooth critical curve, or line

‡ The surface is not necessarily level. The effect of a sloping or irregular surface is considered by the author to cause the line joining points of equal principal stress to be parallel to the surface

§ The difficulties of measuring pressures in certain materials may be realised when it is remembered that a gauge inside a solid might record zero pressure, as the line of pressure goes round the space, similarly in any cohesive material any gauge-testing results would need to be interpreted. The possibilities of Dr Goldberg's pressure measuring apparatus seem attractive, also those of the Mam Roads Research Dept., U.S.A., and of Prof Bridgman's method of utilising the electrical resistance of a metal according to pressure

movement of the wall, consequently, at the face of the wall, the ellipse may be inclined owing to the plane of incipient movement* (the Critical Plane) being vertical. (20)

Wedge Theory.

These theories presume a triangular wedge at the back of a wall of such dimensions that the pressure on the wall is a maximum. For the case of level filling of non-cohesive material, the resulting pressure is the same as that got by the Ellipse. If the author's views, as expounded later for cohesive material, are correct, such triangular wedges are, at best, approximations† to areas with a curved boundary since they presume a constant inclination of the critical plane to the vertical. (21)

COHESIVE NON-FRICTIONAL MATERIAL

If a shear is introduced on any plane not at 45° with the principal axes, a new ellipse must exist whose axes are necessarily inclined to that previously existing. (22)

The theorem stated in (22) may be illustrated by the following example, in which the results obtained are the same as those arrived at by the usual analysis‡ of the case quoted.

A Bolt in a Bracket.

To find the ellipse of stress —

A direct stress " t " exists on one plane and a shear " c ," independent of " t ," exists on the same plane (with a concomitant shear " c " on the plane at right angles)

Referring to Figs 1, 2, 3

Let t be external direct normal stress on AB

Let c be external shear on AB independent of " t "

This is really the case of an inclined stress on one plane

(Fig 1) (23)

These conditions are equivalent to—

(1) (a) Direct Stress $t = (t_1/2 + t_2/2)$ on AB and
 $(t_1/2 - t_2/2)$ on YZ (Fig 2) . . . (i)
 $= t_1/2$ fluid pressure . . . (ii)
 together with—

$t_2/2$ shear on OM, OM' at 45° with OB and . . . (iii)

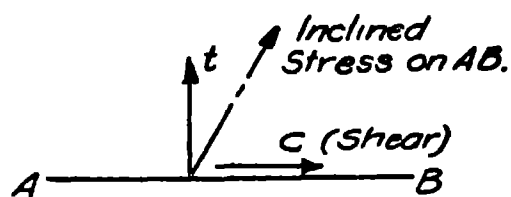
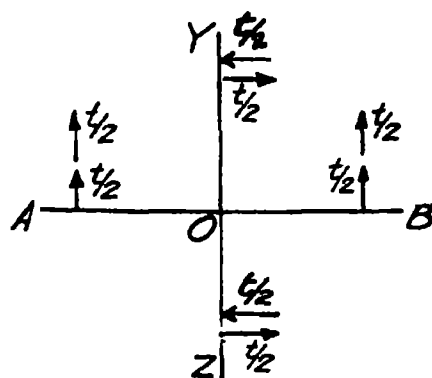
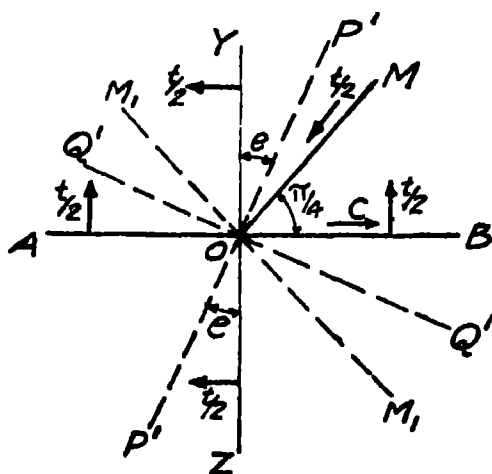
(2) " c " on OB (Fig 3) (iv)

* Dr Jacob Feld used a vertical door pressing on weigh bridges, arranged in such a way that vertical and horizontal stresses on the vertical door could be measured. To the author it seems that a weigh-bridge depends for its action on movement, small, it is true, but movement nevertheless.

Prof Chapman (see discussion in Trans I E A, vol 6, p 311) has made an ingenious attempt to minimise movement.

† A cohesive material, owing to "stickiness," actually holds back a wall for a certain distance from the surface. For cohesive material, the assumption of a solid wedge acting at its centre of gravity seems to the author basically unsound in principle.

‡ See pp 19-21, Andrews, "Theory and Design of Structures"

FIG 1FIG 2.FIG. 3.

Following (13) above—

The direction of the principal stress is fixed by the direction of two shears, namely $t/2$ on OM , " c " on OB Principal stress is where shear = zero * See Fig 3

$$\text{I.e. } t/2 \cos 2(45^\circ - e) = c \cos 2e$$

$$\tan 2e = 2c/t$$

Fig 3

(24)

Conditions of Stress are—

$t/2$ fluid pressure from (n)—

$$\begin{aligned} + t/2 \text{ inclined stress to each plane} &= t/2 \sin 2z_1 \text{ normal} \\ &\quad t/2 \cos 2z_1 \text{ shear} \end{aligned} \left\{ \begin{array}{l} \text{on Plane making} \\ \text{an angle } z_1 \\ \text{with } OM \end{array} \right.$$

$$\begin{aligned} + c \text{ inclined stress to each plane} &= c \sin 2z_2 \text{ normal} \\ &\quad c \cos 2z_2 \text{ shear} \end{aligned} \left\{ \begin{array}{l} \text{on Plane making} \\ \text{an angle } z_2 \\ \text{with } OB \end{array} \right. \quad (25)$$

For the Principal Plane—if q_s is the arithmetical value of the principal stress, which is negative

$$\text{Here } z_2 = (90^\circ - e)$$

$$z_1 = 45^\circ - e$$

$$\text{and } p_1 = t/2 (1 + \sec 2e)$$

$$q_s = t/2 (\sec 2e - 1)$$

(26)

$$\text{Max Shear} = \frac{p_1 + q_s}{2} = t/2 \sec 2e \quad (27)$$

These results† agree with those obtained by trigonometrical resolution

It should be noted that the investigation given above has neglected friction resistance, that is to say, for finding breaking stresses in terms of " c ," though it applies to tensile stress approximately,‡ it will need modification if all normals have a potential resistance to shear due to friction

(28)

It will be observed later that p' , q' is the ellipse representing internal stress at O , found by algebraical summing of separate influences

(29)

Generalisation

Referring to Fig 4

* Any number of planes each with a different shear could be reduced to a shear on one plane, implying necessarily the same shear on the concomitant plane at right angles, and thus the principal plane may be found as shown

† Vide Morley, "Strength of Materials," pp 22 23

‡ Even for tensile stress it presumes $q_s = \text{zero}$, which is not quite true if the specimen has definite size, since a ring of material forms, causing stresses on the interior portion Poissons Ratio in this sense may be a function of e , ϕ , and E (Young's Modulus) Again, shear intensities imply normal compressions, which again imply frictional resistance to tangential movement, the general result of which, then, is a modification as given in the Author's "Critical Planes" Actually Result (24) is a special case of the general equation—

$\tan 2e = c/p_s \pm \cos \phi$

See "Critical Planes" (91)

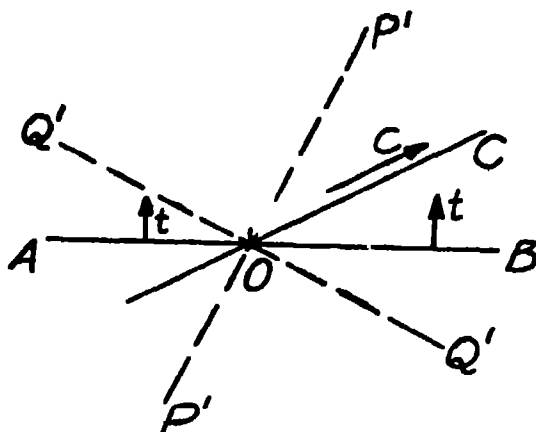


FIG. 4.

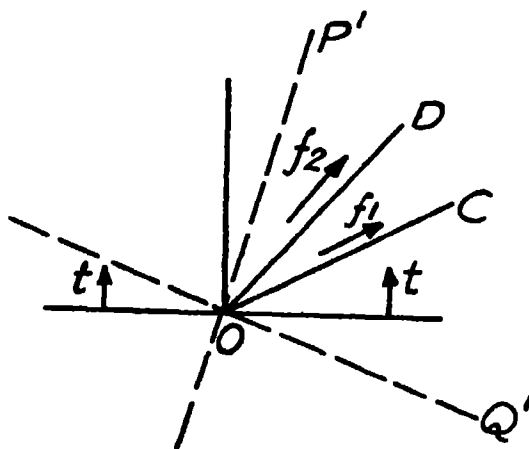


FIG 5.

Suppose c were on a plane making an angle with OB in Fig 4

That is, t on OB , and c on OC , independent of each other

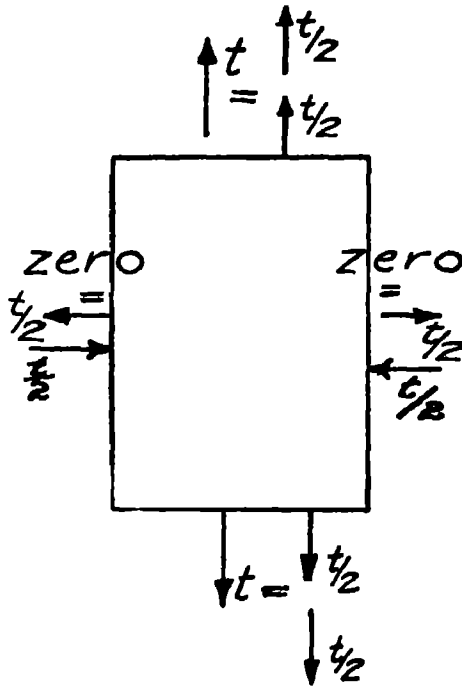
OP_1 , OQ_1 would have position and values corresponding to the planes on which t and c occur

Generally see Fig 5. If f_1 were on OC , and f_2 on OD , that is, f_2 on some other plane OE , the ellipse (p_1, q_1) finally deduced, is that for the algebraical sum of each of the separate normal and shear components, that is, stresses external to each other (30)

Again, (OP^1, OQ^1) would be the ellipse representing internal stresses for equilibrium at O (31)

Failure of Test Specimen.

A specimen usually circular or square in cross-section, whose weight is negligible relative to the applied load, is subjected to an external load causing a stress " t " on one face, and the only apparent external stresses are in the direction of the applied load and the consequential reaction. See Fig 6

**FIG 6**

This Conventional Analysis is based on two main assumptions, namely—

(1) The applied stress is a principal stress (32)

(2) The concomitant principal stress is zero (33)

Presume $+t/2 - t/2$ applied on each of the faces in the direction at right angles to that of the load.

Then, regrouping stresses, it is apparent that (32) represents,

(1) A fluid stress $t/2$ exists throughout, together with—

(2) Shear $+t/2$ and $-t/2$ on two planes at right angles, that is, shear $t/2 \sin 2\theta$ on any plane becoming $t/2$ when $\theta = 45^\circ$ (34)

This is the condition of stress, though apparently there is a single direct stress " t " and reaction " t " on one face. (35)

The ellipse of stress is assumed a straight line The error of this as a practical condition will be discussed later. (36)

Alternatively—

+ $t/2$ on OQ and $-t/2$ on OP causes shears $t/2 \sin 2\theta$,
 I.e. $t/2$ on plane at 45°

In the specimen mentioned, it is not convenient, even if practicable, to apply tension stresses, so that an extra $t/2$ as fluid stress causes—

$$\begin{aligned} t/2 + t/2 &= +t \text{ on } OQ \\ +t/2 - t/2 &= \text{zero on } OP \end{aligned} \quad . \quad . \quad . \quad (37)$$

This added fluid stress does not affect shear intensities (unless friction is taken into account), and the condition taken up is direct stress " t " on OQ , zero on OP , as assumed originally (38)

Again, Alternatively—

" t " is applied as a pressure on one plane OQ this would cause " t " on the plane OP at right angles if the material were fluid

The potential shear resistance of the material is drawn on to provide shear reaction necessary and sufficient to preserve equilibrium. In the analysis this is assumed fulfilled by $q = 0$ (39)

The deductions above, by several alternative methods, have been recorded to show the concordance of several methods, but the primary assumption $q = 0^*$ actually is misleading, since it might be taken to imply that every plane has a resultant stress in the same direction, namely OP . The slightest infinitesimal value of q would put the resultant stress on OP as horizontal instead of vertical (40)

To the author the actual conditions seem to be as follows —

In a test specimen (taken as cylindrical for clearness) and the load normal to the paper—see Fig 7 and Fig 8

* For $q = 0$ as a determinate solution in the Author's treatment (see Results (74) of "Critical Planes") of the subject, if q' and p' are the principal stresses for frictional-cohesive material, and β is the cohesion angle, that is, the angle added to the angle of friction by cohesion (it varies with the ratio of cohesion to p_s), then since—

$$q' = p' \tan \gamma/2 \tan (\gamma/2 - \beta) \quad (i)$$

$$\text{Also } q' = p' \tan^2 \gamma/2 - 2c \tan \gamma/2 \quad (ii)$$

From (i)—

$$q' = \text{zero when } \beta = \gamma/2 \quad (iii)$$

From (ii)—

$$p' = 2c \cot \gamma/2 \quad (iv)$$

In a Frictional Cohesive Material, for the virtual angle of friction to be 90° , then q' is negative

In a Frictional Non-Cohesive Material, for an actual angle of friction of 90° , then q_s is zero

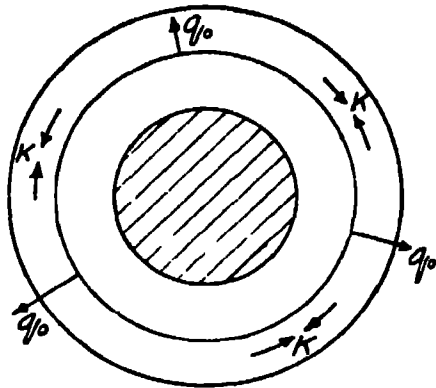


FIG 7

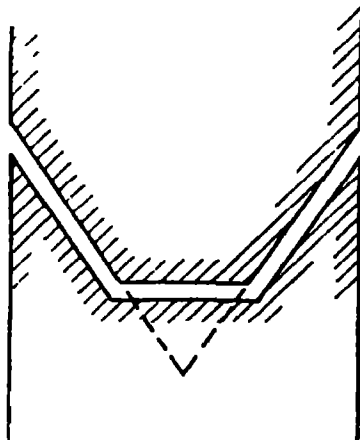


FIG 8

Tension Specimen so that friction phenomena do not appear directly
Near the outside surface q_0 is infinitesimal, consequently, there,

$$\text{Shear} = \frac{p_0}{2} \sin 2\theta,$$

and the maximum shear on plane at $45^\circ = \frac{p_0}{2} \sin \pi/2 = p/2 \dots \dots (41)$

Failure will tend to take place at 45° for a gradually applied load See Fig 8

Towards the interior of the specimen, q_0 has increasing possibilities,
and compression ring stresses, K say, exist, as shown in the sketch
Probably K itself does not cause failure, but combined with p_0 , normal
to the paper, causes longitudinal shears. (42)
This is discussed further under (69) later.

Due to ductility, such shapes occur as in Fig 9, taken from Morley, *Strength of Materials*, p 57

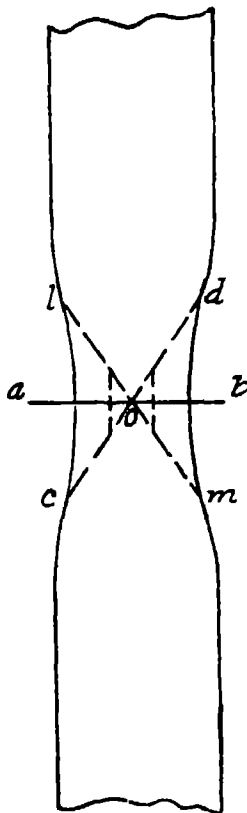


FIG 9

The intensity over ab is greater than that over cd , but the author cannot agree with Morley's statement—

"The intensity of shear stress over such a surface as cd , Fig 44, is not uniform, being greatest at the intersection o , with the plane of minimum cross-section ab "

Primarily the author would read "least" for "greatest" as the intensity

$\frac{p_o - q_o}{2}$ is least at O , but due to contraction of area, as p_o at O is greater

than p_o at " d ," the point of least shear is at some point O' near to O but in no sense is the shear greatest near O (48)

If incipient failure occurs at the outside, then the intensity p_o when

$p_o = \frac{\text{load}}{\text{area of cross-section}}$ increases since the load is distributed over a

smaller area. But if q_0 also increases, the shear intensities (being $\frac{p_0 - q_0}{2} \sin 2\theta$) do not necessarily increase. In fact, if failure by shear is to occur, only so much shear is developed to cause failure, perhaps from this aspect the shear intensity may be regarded as approaching constancy. (44)

Compression Specimen Neglecting friction, the action would be similar to above with Compression written for Tension, with the modification that on the "core" M (see Fig 10) pure compression or fluid stress will exist and no failure takes place, consequently the section failure will be as shown in Fig 11 and 11A. (45)

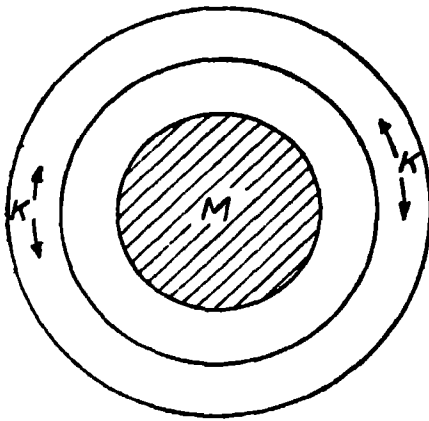


Fig 10

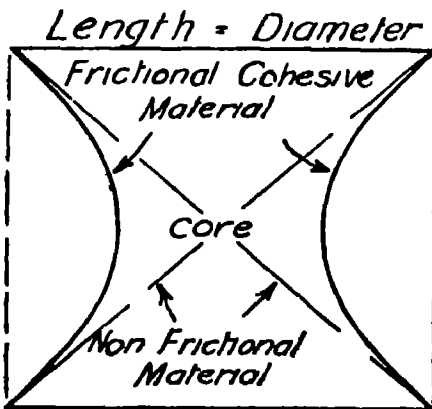


Fig 11

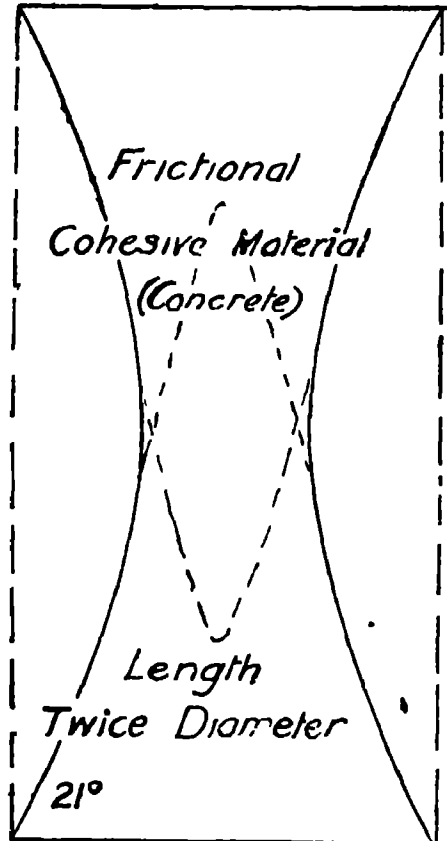


Fig 11A

The shears are $\left(\frac{p_0 - q_0}{2} \sin 2\theta\right)$ when q_0 ranges from zero at the surface to p_0 at the "core," to fit with corresponding intensities of shear. As above, maximum shears are at 45° , and, if friction does not operate, this is the plane of fracture for a gradually applied load (46)

Contraction, expansion, or distortion of the material affects the intensities of loading and causes variations not mentioned above, but the primary phenomena, if friction is not taken into account, appear to be as stated (47)

Guest's Law of Maximum Stress

The following extract from a paper,* "The Flexibility of Plain Pipes," by J R Finniecome, M Eng (Zurich), M Soc Ing C (France), has a direct bearing on the subject —

"The pipe designer is keenly interested in the maximum combined stress, based on the longitudinal and transverse stress, as this will determine the permissible thrust and deflection for the maximum permissible stress

The three principal theories which form the basis for determining the elastic fracture of the material are—

- (1) Maximum Principal Stress (Clapeyron and Rankine)
- (2) Maximum Principal Strain (Saint-Venant)
- (3) Maximum Shearing Stress (Coulomb, Guest, Mohr) (48)

For the calculation of the combined stress the author will apply the third theory, using Guest's law, which has been confirmed by Guest's tests in 1900 for ductile materials. Guest's law is generally used in this country, and is known as the maximum stress difference theory. According to it, the maximum principal stress difference, which is equal to twice the maximum shear stress, forms the basis for the elastic fracture of the material. The maximum shear stress for two perpendicular normal stresses such as the longitudinal and transverse bending stress, is equal to half the difference of these two perpendicular stresses

We thus get the *maximum principal shear stress*—

$$S_m = \frac{p - q}{2} \quad (49)$$

The maximum shear stress is in a plane inclined at 45° to the two planes of the longitudinal and transverse bending stress

In accordance with Guest's law, *the combined stress is equal to twice the maximum shear stress*, and thus we get—

$$\text{The combined stress} = (p - q) \quad \dots (50)$$

* "Metropolitan-Vickers Gazette," May 1928, p 400. The notation has been altered, but otherwise the extract is verbatim

Experiments made by Guest confirm his theory, and the author (M Finnecome) will show from an actual test on a pipe-bend that the theory agrees reasonably well with the value obtained from the above formula "

In the present paper, the correlation of the "Rankine" with the "Guest" theory has been indicated, and will be further discussed below. (The Saint-Venant theory is a refinement that will not be considered at present) (51)

As the author interprets the extract, Guest's Law would seem to be deduced on reasoning as follows —

From (49) The principal stresses are p, q , giving Max Shear =
 $\frac{1}{2}(p - q) = c$ say (52)

Result (50) implies that, as a shear, "c" may be caused by (2c, zero) as principal stresses, there is a "combined" stress (as it is called by M Finnecome) of 2c (53)

The author has shown above, or believes he has shown, that pure shear "c" is concomitant with or caused by normals (+ c, - c), although with some certain extra "fluid" pressure, an infinite combination of principal stresses ($F + c, F - c$) may cause a shear "c," such as (4c, 2c), (3c, c) and so on (54)

There seems no especial reason why (2c, 0) should be that functioning (55)

Only when friction is neglected is the plane of maximum shear the plane of fracture. Of course, if friction does not exist, (p', q') degenerating to p_1, q_1 , where $\frac{1}{2}(p_1 - q_1) = c$ on the plane at 45° with the principal stress, but p_1 is not necessarily, and rarely is, 2c as stated in (50) (56)

It is conceivable that, at the surface of a test specimen, an ellipse 2c, 0 exists, but it does not seem reasonable to assume such a very special condition as a general case (57)

FRictional-Cohesive Material

Author's Method.

Keeping (23) to (31) in mind, he argues as follows —

Non-Cohesive Material with a friction angle ϕ and external load p_0 as a principal stress, is in equilibrium having the other principal stress q_0 .

The principal plane for a perfect fluid is indeterminate, but for a non-cohesive frictional fluid, is determinate, being the direction of the primary applied stress, or is determined by the direction of the plane on which $p_0 \tan \phi$ must equal " s_0 " if such plane is fixed or known .. (58)

In the first stage in the deduction—

For Frictional-Cohesive Material, "c" may be treated as independent of the quantities existing previously

An inclined* stress is introduced on a certain plane OR making an unknown angle with OP_0 (59)

To deduce the angle between the Principal Plane and the Critical Plane, called here " ρ ," the determining conditions are then applied, namely—

The ellipse of stress (p' , q') to be deduced must fulfil the conditions on the critical plane

$$\pi' \tan \phi + c = s' \quad (60)$$

$$\text{and } d/d\theta (\pi' \tan \phi + c) = s' \quad \dots (61)$$

The shear on the true principal plane must be zero (62)

The ellipse (p' , q') deduced, represents equilibrium of internal stresses in the cohesive material, with " c " developed on the Critical Plane, though deduced by algebraical summation† of stresses external to p_0 , q_0 condition (63)

From (60) and (61)—

$$c = \frac{1}{2} p' \tan \gamma/2 - \frac{1}{2} q' \cot \gamma/2 \quad (64)$$

$$\text{that is } q' = p' \tan^2 \gamma/2 - 2c \tan \gamma/2 \quad \dots (65)$$

Result (64) may be known as the *General Equation* ‡

From (62) the direction of the principal stress may be determined, but (p' , q') cannot be to the same axes as (p_0 , q_0) unless $p_0 = 45^\circ$, which it cannot be for any real value of ϕ (66)

The principles enunciated above will now be applied to several standard analyses, and existing standard analyses commented on, in the light of the suggested amended treatment

First, will be considered a Frictional Cohesive specimen under the breaking load in a Testing Machine

* Inclined because a normal had to be introduced to provide for frictional effect of the normals concomitant with " c " as a shear

† The method used bears some analogy to that for finding the stress in a redundant member of a truss

The procedure there is as follows —

Let O be the force in the redundant member R

Presume O as an external force in the direction of R

(Note —The value of O depends on the externally applied loads, but is here assumed independent of them for the present)

Find the stresses in the members of the truss as a determinate structure with R removed

Due to External Loads (1)

Due to O (2)

Compute and add the movements (deflection) of the extremities of R due to (1) + (2) (3)

Equate (3) to the negative strain in R due to O and thus deduce O An alternative analysis by the method of Least Work gives the same result The analogy was suggested to the author by O Fenwick, B E

‡ The modifications for negative q' and normals are investigated in "The General Equation of Stress" by the author

Compression with Friction.

Navier's Theory

This is the essence of all earthwork theories. The standard analysis will be stated and examined. In Navier's Theory,* due to friction and cohesion, the plane of rupture is taken at an angle of $\gamma/2$ with the applied load which is assumed as a principal stress, and the cohesion " c " is connected with the applied stress by the relation† $t = 2c \cot \gamma/2$.

The author takes a different view, and argues as follows — There seems no doubt that for a frictional non cohesive material the Critical Plane makes an angle $\gamma/2 = (\pi/2 - \phi/2)$ with the applied stress (67)

Nor is there any doubt that for cohesive material, neglecting friction, the maximum shear is on a plane at 45° with the principal plane, consequently the Critical Plane is at $\pi/4$ with the applied stress (68)

One would expect that, for a combination of friction and cohesion, the critical plane would lie at an angle between $(\pi/4 - \phi/2)$ and 45° with the direction of the applied stress (69)

For the present purpose the cohesion " c " is the resistance to shear independent of normal stress (it implies, of course, resistance to tension or compression of the same intensity) and is assumed to be the same potentially on all planes. As a consequence, taking the critical plane as that where the curve of $n' \tan \phi + c$ touches the curve of s' (shear), and differentiating, " c " being a constant does not affect the result, the critical plane makes an angle $\gamma/2$ with its own principal stress (70)

The question is—In what direction, and what is the amount of the principal stress?

The author reasons as follows —

Principal Stresses give a 'semi graphical method of expressing the equilibrium of static stresses' they are not permanent nor objective (71)

In all natural phenomena one influence can be presumed to be superimposed on another, and the results should conform in whatever order the influences are applied. Now in a perfect fluid no† definite direction of principal stress exists (72)

For frictional material the critical plane must make an angle $\gamma/2$ with its principal stress. Again, for the reasons given, for frictional-cohesive material, the critical plane is still at $\gamma/2$ with its principal stress, but the directions of the principal stresses may, and do, change (73)

* Morley, "Strength of Materials," p 55, see also (78) later of this paper

† The corresponding results are obtained for earthwork by A. L. Bell (Proc I.O.E., vol. cxcix.), who presumes that the applied load is the principal stress in direction and amount

‡ This, however, actually means that the applied stress (c f gravity) is the principal stress (neglecting cohesion) for infinitesimal friction

It will be understood that the present discussion is dealing with material just about to move along a certain infinitesimal plane, but in equilibrium

For a Frictional-Cohesive Test Specimen—The inclination of the plane of rupture is changed from 45° for a non-Frictional condition to an angle depending on ϕ and c

Again the shape of the specimen would affect the angle of inclination since such depends on the potential " q ", again, if the ratio of diameter to length differs, in two specimens the possibilities of developing the planes of rupture are different

This is found in practice Fig 11A shows diagrammatically the actual phenomena recorded with concrete In a cube the inclination of the Plane of Fracture with the vertical approximates 45° , while, in a cylinder of length twice the radius, the angle may be 21°

Presuming gravity as the load, if cohesion is absent, there is no influence to change the direction of the principal stress* from the vertical, and the internal resistance to shear, due to friction, functions to the extent of diminishing the amount of the other principal stress from p_0 to q_0 (74)

Now, if the shear due to cohesion, which is independent† of the applied stress, being an inherent property of the material, is applied on a certain plane (later to be the critical plane), it seems clear that for new conditions of equilibrium, that is, movement is just ready to begin on that plane mentioned, that the direction of the applied load (called p_0) is not necessarily a principal stress, in fact, the author argues that it is impossible to be so, since " c ," introduced on the plane, must be caused by, or be concomitant with, " c " positive and negative normals, on planes at 45° with the plane on which " c " is introduced (75)

Consequently (unless the critical plane makes an angle $\pi/4$ with the principal plane), a shear must exist on the plane *OR*, that is to say, p_0 is no longer a principal stress The position of the new principal stress is given by the relation that the shear caused by the normals $a + c$ and $a - c$, eliminate the previously existing shear, due to p_0 , q_0 as a frictional material, on the new principal plane, and consequently the new principal plane lies at some angle (called " ϵ ") with the direction of p_0 (76)
The consequence of this is—

The ellipse p' , q' is always inclined to that of p_0 , q_0 by an angle " ϵ ," and is the ellipse representing internal stresses in equilibrium Again, since the critical plane makes the same angle $\gamma/2$ with its corresponding principal plane, both for non-cohesive and cohesive material, then the plane of rupture

* If the direction of the critical plane is fixed (as by a wall) the principal stress may move to conform with the necessary condition making an angle $\gamma/2$ with the critical plane

† Of course, for a certain applied breaking load, functions of ϕ , c , and applied load p_0 exist, connecting the various quantities The value p_0 is that known as the "compressive strength", it will vary with the dimensions of the specimen The value of " c " is the resistance to shear Pure tension, like pure compression, cannot cause shear A pure shear c implies tension " c ," and compression " c ," respectively on each of the two planes at right angles to each other

for cohesive material makes an angle* ϵ' with the plane of rupture for non-cohesive material having the same characteristics apart from cohesion, and in earthwork a curve develops as shown in Fig 12.(77)

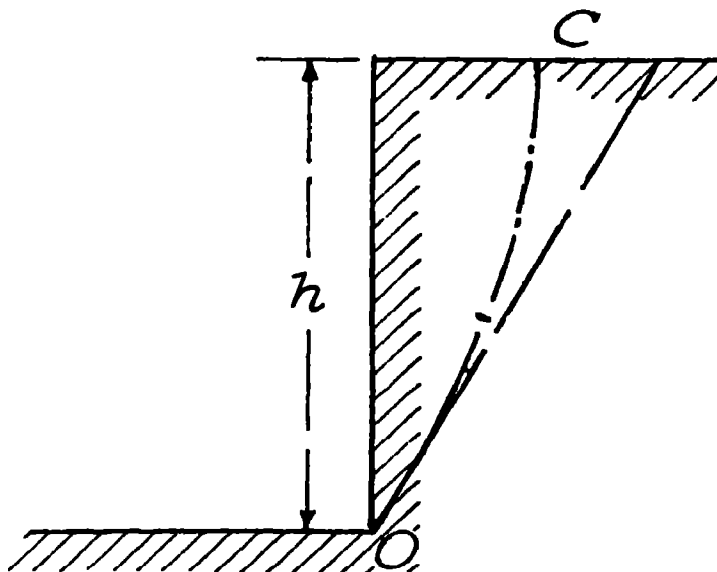


FIG 12.

Morley's analyses will be examined now in the light of the author's views expressed above

In his exposition of Navier's Theory, Morley ("Strength of Materials," p 55), writes—

$$\text{Normal stress on plane} = p \sin^2 \theta \quad (i)$$

$$\text{Shear stress on plane} = p \sin \theta \cos \theta \quad (ii)$$

$$\text{Resistance to shear} = \mu p \sin^2 \theta \quad (iii)$$

These could be true only if q = zero, and if p is a principal stress† .(78)

Actually, in the author's view,

$$\text{Normal} = p' \sin^2 \theta' + q' \cos^2 \theta' \quad (iv)$$

$$\text{and Shear} = \frac{1}{2} (p' - q') \sin 2\theta' \quad (v)$$

$$\text{Resistance to Shear} = \mu(p' \sin^2 \theta' + q' \cos^2 \theta') \quad \dots \quad (vi)$$

where p', q' are the principal stresses for the actual ellipse presuming friction, and θ' is the angle the plane makes with the principal stress p' ..

The maximum shear for any ellipse is always at 45° with the principal stress, being there $\frac{p - q}{2}$ For tension, if friction does not function, failure

* Near the surface of earth under gravity, the inclination of the critical plane with the principal plane for cohesive material is not 45° , owing to the fact that friction does not function when resultants are negative (Tension)

† That is to say, p cannot be the normal component of an applied inclined stress.

takes place of maximum shear, that is, at 45° with the line of applied stress (79)

$q = 0$ implies that the ellipse of stress is a straight line, that is, that the intensities on every plane are in the same direction, i.e. along OP

If q is given any value, positive or negative, the intensities on planes making a small angle with OP are nearly at right angles to OP instead of being along OP , as follows from the erroneous assumption of $q = 0$ * Practically, a straight line as an ellipse is unattainable (even for negative values of q , up to a certain value, the normals are compressive, and friction may function) Actually $q = 0$ may exist at one point intermediate between q positive and q negative

It is necessary to take q as having a real value and deduce the resultant effects, then when q is infinitesimal, no anomalies arise (80)

Alternatively—

Drawing a series of layers in the material as shown in the Sketch Fig (13)—

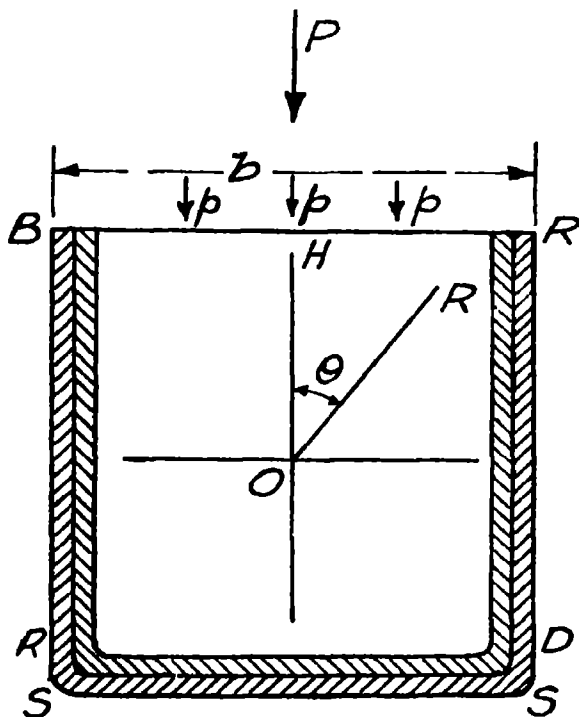


FIG 13.

* A definite analogy exists with column analysis. In that analysis, the assumption that absolute zero exists, that is, that loading has zero eccentricity, and/or the column has zero initial bending, has caused much discussion, more or less futile, similarly with an assumption of a zero principal stress in earth pressure analysis. (Vide "Column Design Curves," Trans. I E A., vol 9, by the author)

- (1) If the material is fluid, then $q = p$
- (2) If the material is fluid-frictional, that is, all resistance to tangential movement is proportional to the normal,* some lessening of q takes place, but the external influence introduced on fluid conditions only arises as a consequence of the application of " p ," and thus *the new principal stress has the least value consistent with equilibrium*, that is, for a critical plane OR ,
 $n \tan \phi = s$ from this $q_0 = p_0 \tan^2 \gamma/2$ (81)

If cohesion is introduced on the fluid conditions, than " c " on any plane implies that the principal axis OP will be inclined to OP_0 and—

$$\begin{aligned} p_1 &= p_0 + f(c_1 \theta) \\ q_1 &= p_0 - f(c_1 \theta) \end{aligned}$$

Such a condition might arise in non homogeneous material (82)

When the plane on which " c " is introduced is at 45° with OP_0 , OP_1 and OP_0 are coincident,

$$\begin{aligned} \text{and } p_1 &= p_0 + c \\ q_1 &= p_0 - c \end{aligned}$$

Only if $c = p_0$ can $q_1 = \text{zero}$ See Fig 14

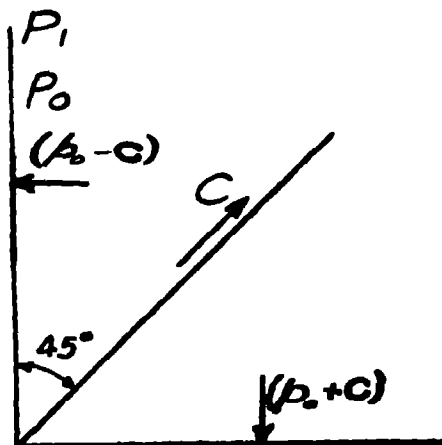


FIG 14.

In such a case—

$$\begin{aligned} p_1 &= 2c \\ q_1 &= 0 \end{aligned} \quad \dots \dots \dots (83)$$

* Not necessarily as the first power, but it is assumed so in the present solution; the general reasoning is not affected thereby

This, which is a limiting theoretic condition, unattainable probably, has been assumed as that for the general case in Guest's Law as expounded by M. Finnicombe in (50)..... . (84)

"Pressure in Clay," by A. L. Bell.

This analysis generalises on the limiting assumption of a constant direction of the principal stress, presumed the same, in direction and value, for a cohesive material as for a non-cohesive material, and is thus a Special Limiting Case

If q_0 is written for the concomitant principal stress when cohesion is present, then Mr Bell's result becomes*—

$$q_0 = p_0 \tan^2 \gamma/2 - 2c \tan \gamma/2 \quad \dots \quad (85)$$

Without Cohesion—

$$q_0 = p_0 \tan^2 \gamma/2 \quad \dots \quad (86)$$

From the Generalisation of (64)—

$$q' = p' \tan^2 \gamma/2 - 2c \tan \gamma/2$$

It is clear that Mr Bell assumes p' to be coincident with p_0 in value and direction, also necessarily, that q' is coincident with q_0 in direction, that is, that a vertical plane only offers a resisting stress normal to itself. In other words, that the vertical plane is frictionless and non-cohesive. Thus it appears that the Bell results are those for a Limiting Case (87)

It can easily be seen also, that the formulæ of Rankine, Navier, and Guest are for special limiting cases of the General Equation (64) obtained by writing " c ," q , ϕ as zero respectively (88)

The author considers that in its application to Earth Pressure, Strength of Materials, and other Engineering Problems, the General Equation is not limited by the restrictions of the Limiting Cases mentioned

The limit of applicability of the General Equation is $q' = -c \tan \gamma/2$, since with a larger negative value of q' , the resultant on the critical plane is zero or negative, and the equations connecting q' , p' , and c are modified accordingly †

Unsupported Bank

As usually presented—

From the relation $p = 2c \cot \gamma/2$

If w = weight of material

h = height of unsupported material, that is, the depth of the trench,

then failure will take place

when $wh = 2c \cot \gamma/2$

This is known as Scheffler's Analysis,‡ and has been re deduced by Mr Bell (89)

* Pointed out by A. Burn, "Critical Planes," p 225

† See "The General Equation of Stress" by the author

‡ Warren, "Engineering Construction," part 1, p 26

From the Wedge of Rupture, or as shown otherwise by Prof Ketchum—

$$\omega h = 4c \cot \gamma/2$$

If the analyses were correct, these two expressions, one of which is double the other, should be the same . . . (90)

The author's treatment of the subject maintains that both results are wrong (though the latter has some approximation to that considered correct) . . . (91)

The author's analysis gives a curve CO as that for failure at O in the sketch (see Fig 12)

The height that a bank will stand unsupported should be deduced from this curve (92)

The characteristics of the commoner engineering materials will be used as illustrations

MATERIALS UNDER TEST

The applied load at failure in compression tests (in this deduction p_0) is known as the "Compressive Strength" This "*Compressive Strength*" is not a basic unit for a certain material, it is a function of the resistance to shear " c " (that is, the shear strength in pure torsion) and the angle of friction ϕ , also of the shape of the specimen, again, the inclination of the plane of rupture " ρ ," to the direction of p_0 is a function of " c ," " p_0 ," and ϕ , deduced in the author's treatment by using a subsidiary angle " e " Thus is seen in test specimens the "compressive strength" of a cube (Fig 11) is different for a cylinder having length equal to twice the diameter (Fig 11A), a larger intensity is obtained with a larger specimen (93)

Cast Iron.

Compression

The material has properties as follows* .—

Shear Resistance in Torsion, with failure at 45° with the axis of revolution
 $= 18,000$ lb. per sq. in.

"Compressive Strength"

$= 90,000$ lb. per sq. in.

Tensile strength $= 25,000$ lb per sq. in.

The Fracture Angle is of the order 35° . See Fig. 15.

Compression

$$\text{Here } \frac{c}{p_0} = \frac{18000}{90000} = 2$$

$$\text{Since } \sin 2e = \frac{c}{p_0} (1 + \sin \phi) \text{ or}$$

$$\tan 2e = \frac{c}{p_0 - c \cos \phi} (1 + \sin \phi)$$

$$\text{Here } \sin (\phi - 20^\circ) = \frac{1}{5} (1 + \sin \phi)$$

$$\phi = 39^\circ.$$

$$e = 9^\circ 30'.$$

* Vide "Merriman's Pocket book," p 277

The various planes are shown in Fig 15

Tension

The shear intensity can never reach the resisting capacity, so that failure is by direct tension

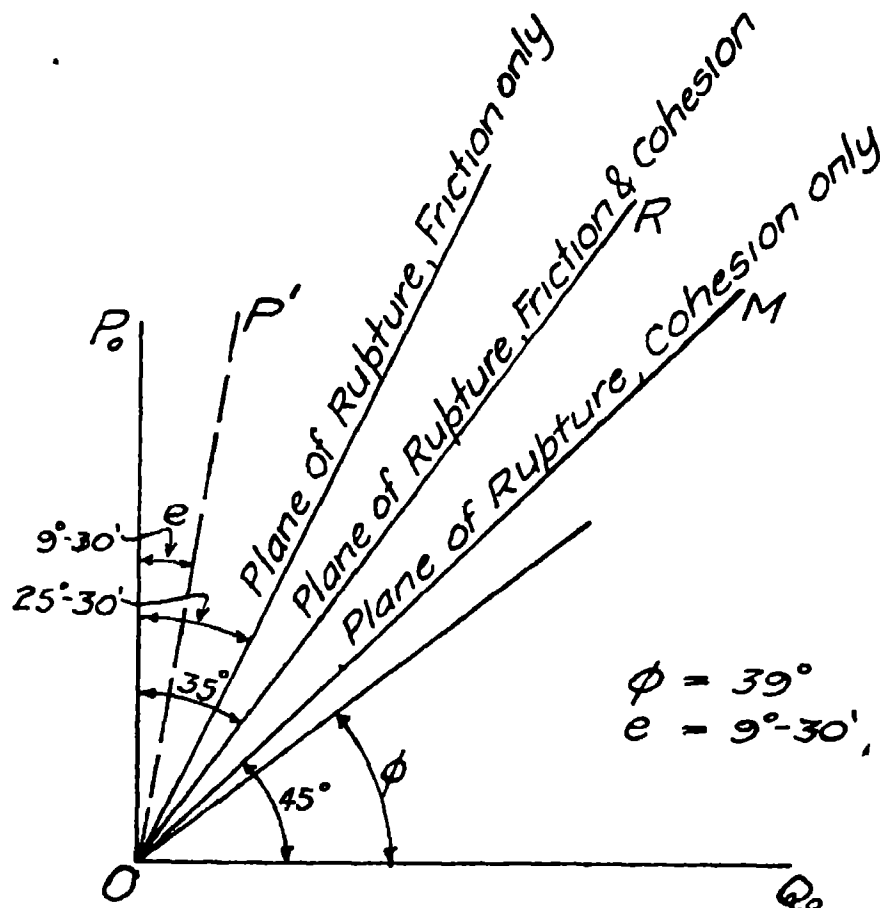


FIG 15.

Steel has compressive and tensile strengths much the same, so that friction effects are small. This may be accounted for by the fact that during the process of manufacture high temperature and compressions are applied, to which subsequent pressures are small comparatively.

In tension, the phenomena have been examined above. In compression* the metal assumes fluid properties, i.e. plastic flow.

* The compression strength is deduced from beam tests. Fracture does not occur in compression.

Concrete is usually tested in compression

"Compressive Strength," say 2,100 lb per sq in

Shearing Strength, say 300 lb per sq in

Evidently the value of the Friction Angle is high

The Angle of Inclination of the Fracture plane is 21°

$$\text{Here } \frac{c}{p_0} = \frac{1}{7}$$

$$\sin(\phi - 45^\circ) = \frac{1}{7} (1 + \sin \phi)$$

$$\phi = 64^\circ$$

$$e = 9^\circ$$

Figs 11 and 11A, above, show typical results for concrete

(94)

CONCLUDING SUMMARY

To summarise From primary facts—

If a material has cohesive resistance " c " to shear

Then movement may be caused on any plane, *OR* say, by applying

" c " as compression on one plane at 45° with *OR*, say *OP*

" c " as tension on the other plane at 45° with *OR*, say *OQ*

The stresses mentioned cause, or are concomitant with, shear " c " on *OR* (i)

It is not convenient to apply loads in this way

Add F as a "fluid" pressure to (i)

Then $F + c$ on *OQ* that is p on *OQ*

$F - c$ on *OP*, that is q on *OP*,

cause shear " c " on *OA* (ii)

(Normals F exist on all planes, but these do not affect shear)

That is, if " p " be applied in a certain direction (cf vertical) and $q = (p - 2c)$ at right angles, the plane of max shear is at 45° with *OP* (iii)

It will be noted above in (i) and (ii) that—

F may have any value

that is, p and q any value provided that

$$q = (p - 2c) \quad (95)$$

(If $F = c$, then $p = 2c$, and $q = 0$, as assumed in (50) above, and so on)

Also, that p and q may be in any direction, but that the critical plane is at 45° with the direction of p or q

If friction does not function, and if zero on *OP* be attained, this is the end of the matter (96)

Actually, however, a certain stress p_0 is applied normally to the material, and the material has cohesive resistance to shear " c " independent of any applied load, and a frictional resistance to shear proportional to whatever normal stress exists

To have " p_0 " as a normal stress on one plane, and " c " as a shear on another plane, each independent of the other an ellipse (p' , q') must exist, whose axis is inclined to the direction of p_0 (*vide* Generalisation of "Bolt in a Bracket" case) " c " is introduced as independent of p_0 , but the final ellipse p' , q' deduced, represents internal equilibrium, and fulfils all the conditions laid down (97)

The solution of the ellipse for " c " as a function of p_0 is obtained by using the conditions—

- (1) That, as a frictional material only, certain stresses exist throughout,
- (2) That to overcome cohesion other stresses must be introduced,
- (3) That an ellipse (p' , q') representing equilibrium of stresses so deduced, is that to be used for getting relative values of variables (98)

The ellipse (p' , q') deduced, representing the condition of equilibrium of stresses just before failure, that is, the limiting conditions are reached on one Critical Plane, determines the intensities on any plane for that moment of time (99)

In soils under gravity, a curved critical plane develops. The equation of this, and the many important results following, are developed in the author's paper "Critical Planes". In this present paper, the author has attempted to expound the basic change he suggests in the theory formerly accepted (100)

The Essential Oil of *Eucalyptus Andrewsii* from Queensland.

By T G H JONES, DSc, A A C I, and M WHITE, BSc

(Read before the Royal Society of Queensland, 24th September, 1928)

Eucalyptus Andrewsii was named by Maiden with the record that it was common in the New England district of New South Wales and that it extended into Queensland, but with no definite locality assigned. Later he recorded it from Stanthorpe. Mr C T White, who first brought the Queensland specimen under our notice, says that the tree is abundant on the road between Toowoomba and Crow's Nest, and that when he first obtained specimens he named it as a variety (var *inophloia*) of *E. hæmastoma*. In the Toowoomba-Crow's Nest area it is known most commonly as "peppermint," though sometimes simply as "stringybark."

Examination of the essential oil obtained from leaves supplied through courtesy of the Forestry Department has shown it to be identical in chemical character with the oil of *E. Andrewsii* described by Baker and Smith,¹ and from this it would appear Mr White's view expressed to us, that the tree named by him as a variety of *E. hæmastoma* (var *inophloia*) is referable to *E. Andrewsii*, is correct.

The oil, which was obtained from the leaves to the extent of 1.25 per cent, consisted very largely of 1- α -phellandrene accompanied by relatively small amounts of p-cymene, piperitone (less than 5 per cent), piperitol, and aromadendrene, and in view of high phellandrene content is therefore of economic value. Cineol and pinene were not detected.

EXPERIMENTAL

170 lb of leaves from Peachey, collected at the end of October 1927 and distilled for several hours in steam, gave 1,100 ccs of oil possessing an agreeable phellandrene odour.

The following constants, indicative of high phellandrene content, were recorded. Those of *E. Andrewsii* (Smith) are also appended for comparison.

		<i>E. Andrewsii</i>
d_{15}^4	8770	d_{15}^4 8646
$[\alpha]_D$	-60.9	$[\alpha]_D$ -41.5
n_D^{20}	1.4810	n_D^{20} 1.4831
Acid number	nil	
Ester value	14.22	
Acetyl value	56.24	Acetyl value 57.67

¹ Research on the Eucalypts, Baker and Smith, second edition, p. 303

300 ccs were fractionated at 4 mm pressure using a 12 pear column and the following fractions collected —

				d_{15}^4	α_D	n_D^{15}
(a)	0 —	50° C	212 ccs	8516	-63.5	1.480
(b)	50° —	70° C	30 ccs	8815	-42	1.4832
(c)	70° —	80° C	36 ccs	9329	-35	1.4845
(d)	80° —	105° C	18 ccs	9592	-19	1.4900

Fraction (a), which constituted the bulk of the oil, was extracted with 50 per cent resorcin solution, but no cineol could be detected in the extract. Further refractionation failed to show any appreciable quantity of pinene, and all tests for this terpene were negative. The presence of 1- α -phellandrene was confirmed by the usual nitrosite reaction. As commercial phellandrene is recorded as containing p-cymene it appeared of interest to examine this fraction for this constituent. Removal of the bulk of the phellandrene by repeated nitrosite formation gave a residue which, after distillation several times over sodium, showed the constants recorded for p-cymene, viz., b.p. 175° C d_{15}^4 8662, n_D^{15} 1.485. Identity with this substance was confirmed by oxidation to p-hydroxy isopropyl benzoic acid m.p. 155.5° C.

The crude phellandrene examined in this way showed a cymene content of approximately 10 per cent.

Fractions (b) and (c) were taken separately with neutral sodium sulphite solution to extract piperitone and the residue again fractionated. Further phellandrene was separated, leaving a residue which possessed the constants recorded for piperitol, viz. d_{15}^4 9345 n_D^{15} 1.482 (Found C 77.9 H 11.6. Required C 78.1 H 11.2). The amount available was too small for further examination.

Piperitone—Separated from the sulphite solution the absorbed oil possessed the characteristic odour of piperitone. The following constants were recorded —

$$d_{15}^4 \text{ 9375, } n_D^{15} \text{ 1.4816} [\alpha]_D -6$$

(Found C 78.5 H 10.4. Required C 78.9 H 10.5)

Identity with piperitone was confirmed by reduction with sodium amalgam and alcohol to the dimolecular ketone M.P. 148° C. Preliminary examination of the original oil by bisulphite extraction indicated a piperitone content not greater than 5 per cent.

Fraction (d) was distilled several times over sodium and again fractionated. Phellandrene was still present but the bromine-acetic acid reaction for sesquiterpene was well pronounced, and some sesquiterpene, presumably aromadendrene, was therefore present in traces only in the oil.

The authors wish to express their thanks to Mr C. T. White for suggesting this investigation.

Petroleum from the Roma Bores.

By J B HENDERSON, F I C, and W J WILEY M Sc

(Read before the Royal Society of Queensland, 29th October, 1928)

In 1897 the first bore at Roma was sunk to a depth of 1,678 feet to obtain a supply of water for the town. To obtain a further supply a second bore was sunk close to No 1 and in October 1900 reached a depth of about 3,700 feet. At this depth a flow of natural gas was obtained. This gas had a smell resembling kerosene. An analysis of the gas made in the Government Chemical Laboratory in 1900 by the old absorption methods showed the presence of hydrocarbons other than methane. The results summarised were as follows —

	Per cent
Carbon dioxide . . .	1.5
Marsh gas (CH_4) . . .	72.0
Ethane and other hydrocarbons . . .	23.1
Inert gases (by difference)	3.4
	<hr/> 100.0 <hr/>

Although we did not then know it, those results were conclusive proof that the gas was a petroleum gas and not a coal seam gas. Much work done on natural gases in America has shown that coal seam gas does not contain hydrocarbons other than methane while petroleum gas does. The gas was accompanied by a considerable amount of water, the yield of gas having been estimated at about 70,000 cubic feet per day and of water at 183,000 gallons per day.

The gas was allowed to run to waste for nearly six years. The Roma Town Council then reticulated the town to supply the gas to householders. The gas was connected up in June 1903, but unfortunately it ceased to flow within a very short time of being diverted through the separator into the gasometer. Obviously the checking of the flow by the separator caused the water to accumulate in the bore until its pressure choked off the gas. Reports were published in the newspapers that when the gas ceased there was some light clear oil found floating on the water for a very short time after the gas flow ceased. Unfortunately no samples of the oil could be obtained officially later, nor other absolutely direct evidence about the oil. Its occurrence, however, is quite in accordance with its being a condensate from the gas when the rate of flow was being choked down by the accumulating water, with the resultant greater cooling of the gas and condensing of the heavier vapours.

A company was then formed and a third bore put down in the same vicinity. In October 1908 this bore also got gas at about the same depth, 3,700 feet. The gas, however, caught fire immediately after coming in.

and burned down the derrick. The fire was extinguished, but the gas soon ceased to flow through water arising, and the bore was abandoned. No sample of this gas was analysed.

The Government then put down a fourth bore in the same vicinity, and got gas also at about 3,700 feet, in August 1920. The flow of gas when partly shut off to give 87 lb pressure at the outlet valve was not less than 10,000,000 cubic feet per day, accompanied by 100,000 gallons of water in the same time. This water was more saline than any of the waters which any of the bores had passed through in the higher strata. It is to be noted that these three bores which gave petroleum gas are so close that a circle of 200 yards diameter would easily include all of them.

This gas from No. 4 Bore gave the following results on analysis —

	Per cent
Carbon dioxide	1.0
Methane	63.2
Ethane and other hydrocarbons	27.0
Inert gas	8.8
	<hr/> 100.0 <hr/>

The specific gravity of the gas, air being taken as 1, was 0.65 by the Schilling diffusimeter.

Professor Steele, of the University of Queensland, found helium among the inert gases. He estimated the proportion as about 1 part in 12,000.

The gas when extracted with mineral seal oil in absorbers gave petrol at the rate of about 150 gallons per 1,000,000 cubic feet per day, a proportion which should prove of great economic value. Work ceased in 1922 on this, the third bore which had got gas from the same geological horizon. This bore became blocked, and while trying to clear it a showing of heavy petroleum was obtained at about the 2,750 foot level. A sample of this petroleum, which is a soft, dark brown wax at ordinary temperatures, is shown on the table.

A fifth bore was put down close to the others by the Roma Oil Corporation, and a flow of gas was obtained at about the same level, in September 1927. This gas had a similar composition to that previously found in the other bores, and was found to contain about the same yield of petrol, 1.2 pints per 1,000 cubic feet. Its specific gravity was also 0.65 by the Schilling diffusimeter (air = 1).

The flow of gas, with the opening adjusted to give a pressure of 450 lb per square inch at the top of the casing, was about 600,000 cubic feet per day.

The bore is 3,701 feet deep. The 8 inch casing is cemented in at 3,555 feet, shutting off all gas and water above that depth. The hole is not cased below that level, the bottom 146 feet being "open hole." Gas was obtained during the last 42 feet bored. In the Government Bore (No. 4, Roma)

where a mud fluid was not used in the boring to fill the pores of the strata, gas was obtained during the last 100 feet

A 3-inch swabbing tube extends down for about 3,000 feet. The swabbing tube is connected gastight to the top of the 8 inch casing, and the outlets from both are controlled by valves

The valve of the 3-inch tube is opened on every second or third day for a short time. Water is blown up, accompanied by a little light oil. Obviously there must be water in the lower part of the bore above the level of the bottom of the swabbing tube, and the upward rush of the gas carries the water and oil with it exactly as in an ordinary "air lift" for water

This water must of course be entering the bore below the level of the 8-inch casing, probably it is coming from the same stratum as the gas. It is much more saline than any water in the upper strata. The most saline of these contained 25 grains of chlorine (calculated as sodium chloride) per gallon, while the water accompanying the gas contained 212 grains of chlorine per gallon (calculated as sodium chloride). The amount of water blown up the tube depends on the time during which the blowing is continued. For the first twenty days it was about 4,200 gallons, or an average of 210 gallons per day. As the water rose high enough in the bore on several occasions during the first few months to stop the flow of gas, evidently it was coming in at a slightly greater rate than it was being blown out.

The water was not often much emulsified with the oil, and the bulk of the emulsion generally separated rather quickly and easily. A proportion of the emulsion was occasionally rather persistent, and was broken up by heating with a steam coil.

The emulsion was coloured blue black as it reached the surface. It was noticed that, if the oil containing the emulsion were left exposed to the air, a brown red deposit of ferric hydroxide was obtained and the black colour disappeared. The black deposit was ferrous sulphide, which oxidised to ferric hydroxide. Obviously, the oxygen from the air dissolves in the oil and oxidises the sulphide.

The oil obtained from this bore, amounting to about 10 gallons per day over the first six months of the flow, probably caused more interest than any of the other facts about the bore. It is a clear, volatile liquid, about midway in its properties between the ordinary petrol and the kerosene of commerce. This volatility, coupled with the small amount obtained, and other factors, suggested that gas without oil enters the bore, and that, as the gas cools on expanding and rising, it deposits the oil, i.e., that the oil is a condensate. In order to test this hypothesis, the following work was done on a sample of the Roma oil received in the Government Chemical Laboratory in November 1927.

The volume of vapour of a given liquid which can be carried by a gas at a given temperature and pressure is a function of the vapour pressure

of the liquid at that temperature Dalton's "Law of Partial Pressures," as applied to vapours, can be stated in the form —

$$\frac{\text{Volume of vapour}}{\text{Total volume}} = \frac{\text{Pressure of vapour}}{\text{Total pressure}}$$

Hence, knowing the total pressure, total volume (i.e., volume of gas and vapour), and vapour pressure, the volume of vapour which can be carried by the gas is readily calculated. Knowing the vapour density and specific gravity of the liquid vapourised, the weight of vapour can be calculated and from this the volume of liquid corresponding to the calculated weight of vapour.

The Roma oil, however, consists of a mixture of many liquids, and the above calculation could not be applied directly to such a mixture. Therefore, the first work done on the sample of oil was a fairly thorough fractional distillation, splitting it up into a number of fractions having a boiling point range of 5° C. Each of these fractions on partial evaporation would yield a vapour phase approximating in composition to the remaining liquid portion of the fraction, and a calculation, from the vapour pressure, of the volume of its vapour in a gas would be approximately correct.

The experimental work, therefore, involved a fractional distillation of the oil in order to split it up into fractions of small boiling-point range, and the determination of the vapour pressure, vapour density, and specific gravity of these fractions.

The results of this experimental work are shown in the following table, the experimental methods and details being given in the Appendix —

TABLE I

Fraction	Boiling Point °C	Proportion Present in Oil	Vapour Pressure M M, of Mercury				Vapour Density, Lb per Cub Ft of Vapour at N T P	Molecular Weight	Specific Gravity at 27°C
			180°F	160°F	150°F	100°F			
1	Start to 100°C	Per Cent 3.21					0.276	99	0.732
2	100-105	0.78					0.290	104	0.745
3	105-110	0.69					0.307	110	0.742
4	110-115	0.89					0.318	114	0.736
5	115-120	3.22	258	180	153	55	0.327	117	0.743
6	120-125	4.08	227	150	122	39	0.327	117	0.754
7	125-130	1.93	193	131	107	35	0.335	120	0.763
8	130-135	2.12	155	103	83	23	0.349	125	0.761
9	135-140	3.25	132	81	65	19	0.363	130	0.755
10	140-145	3.53	114	75	61	19	0.359	132	0.756
11	145-150	4.71	104	69	58	19	0.374	134	0.766
12	150-155	5.56	86	60	53	19	0.388	137	0.773
13	155-160	10.80	75	50	43	17	0.394	141	0.766
14	160-165	9.59	61	41	34	11	0.408	146	0.766
15	165-170	5.89	58	39	33	11	0.414	148	0.773
16	170-175	5.78	55	36	31	11	0.427	151	0.782
17	175-180	5.05	43	23	18	5	0.438	157	0.780
18	180-185	4.29	41	16	12	2(?)	0.450	161	0.782
19	185-190	3.25					0.458	164	0.789
20	190-195	3.21					0.464	166	0.793
21	195-200	2.23					0.480	172	0.797
22	200-210	3.87							0.803
23	210-220	2.83							0.804
Residue	220-	6.52							0.837

The other factors necessary for the calculation as to whether the oil can be carried as vapour in the gas are—

- (a) Daily flow of gas—Mr Ross's determination of 600,000 cubic feet (at N T P) per 24 hours when the rate is adjusted to give 450 lb pressure is taken
- (b) Pressure in 8-inch casing at top of bore—450 lb per square inch noted from gauge
- (c) Pressure in gas strata at bottom of bore—1,400 lb per square inch, estimated by Mr W A Cameron and Mr Ogilvie
- (d) Temperature in 8-inch casing at top of bore—Mean taken at 100° F
- (e) Temperature in gas strata at bottom of bore—Estimated by Mr Ogilvie at 160° F (Temperature at bottom of near-by Government oil bore determined by Mr W A Cameron in 1920, 180° F)

Fraction 14 can be taken for an example of the calculation used for each fraction

For fraction 14—

Specific gravity = 0.768

Vapour density = 0.408

Vapour pressure at 160° F = 41 mm of mercury
= 0.79 lb per square inch

Vapour pressure at 100° F = 11 mm of mercury
= 0.21 lb per square inch

At 1,400 lb pressure and 160° F, 600,000 cubic feet (measured at N T P) of gas would be capable of carrying $\frac{0.79}{1.400} \times 600,000 = 338$ cubic feet of the vapour of fraction 14 (measured at N T P). 338 cubic feet of this vapour would weigh $338 \times 0.408 = 138$ lb. This amount stated in gallons is $\frac{138}{10 \times 7.68} = 18$ gallons.

Each 600,000 cubic feet of gas in the strata, taking the pressure at 1,400 lb and the temperature at 160° F, is therefore capable of containing the vapour of 18 gallons of that part of the oil represented by fraction 14.

A similar calculation shows that the gas, when the temperature has fallen to 100° F at the top of the bore and the pressure has fallen to 450 lb per square inch, would only be capable of containing as vapour 14.8 gallons of that part of the oil represented by fraction 14.

In other words, if, under the conditions stated, the gas in the strata were saturated with the vapours of fraction 14, it would deposit 3.2 gallons of that fraction for each 600,000 cubic feet of gas which came up the bore.

It is here assumed that there is only gas at the bottom of the bore. If the gas is flowing through a liquid another case presents itself. For a mixture of such closely related hydrocarbons it can be assumed that Henry

and Raualt's Laws will approximately hold. That is, that the vapour pressure of each constituent in the mixed "oil" will be proportional to its concentration in the oil. To illustrate the calculation in this case we will again take fraction 14.

Fraction 14 is present in the oil in the proportion of 9.59 per cent. Its vapour pressure when in equilibrium with the oil at 160° F. then will be $\frac{9.59}{100} \times 41 \text{ mm}$. By continuing the calculation exactly as before, we find that 600,000 cubic feet of gas would carry 1.72 gallons of this fraction.

At 100° F., 1.42 gallons could be carried.

A similar calculation for each of the other fractions of which the vapour pressure was determined yields the following results —

TABLE II

Fraction	Boiling Point °C	Proportion Present in Oil	Gallons of Fraction which could be held as Vapour by 600,000 Cub Ft of Gas (Measured as N.T.P.)		Gallons Actually Yielded by 600,000 Cub Ft	Gallons which could be held in Equilibrium with the Liquid	
			At 160°F	At 100°F		At 160°F	At 100°F
5	115-120	3.92	65.3	61.5	0.392	2.17	2.04
6	120-125	4.03	53.8	43.4	0.403	2.17	1.75
7	125-130	1.91	47.7	42.2	0.193	0.92	0.81
8	130-135	3.12	39.4	28.8	0.312	1.23	0.84
9	135-140	5.35	32.2	23.7	0.535	1.72	1.27
10	140-145	3.53	30.3	24.0	0.353	1.07	0.85
11	145-150	4.71	28.2	24.0	0.471	1.33	1.11
12	150-155	5.56	24.7	21.5	0.556	1.37	1.36
13	155-160	10.80	21.4	22.5	1.080	2.31	2.43
14	160-165	9.59	18.0	14.8	0.959	1.72	1.42
15	165-170	5.39	17.4	14.9	0.539	0.94	0.90
16	170-175	5.78	16.2	15.3	0.578	0.93	0.88
17	175-180	6.05	10.8	7.3	0.505	0.5	0.37
18	180-185	4.29	7.7				
Total		72.45					

It will be seen that for all the fractions of the oil examined (with the exception of fraction 13) the gas in the strata could contain vapours of these liquids which would, if the gas were saturated, deposit as the gas cooled and expanded on coming to the surface. Taking these figures in conjunction with the proportion of each 5°C fraction found in the oil and the daily yield of oil (about 10 gallons), it will be seen that the gas in the strata contains a fairly high proportion of the possible amount of the less volatile fractions. A proportion of the vapours of the higher boiling-point fractions condenses in the bore as the temperature decreases, and the condensed liquid absorbs some of the vapours of the more volatile fractions. As these fractions condense they flow down to the water, and come up with the gas and water when the pressure is released at the top of the 3-inch swabbing tube.

The results show that a yield of about 10 gallons per day could be quite easily obtained by condensation of vapours from the gas under the conditions stated. They also indicate that under these conditions the "oil" exists in the strata as vapour in the gas.

The work done on this "oil" naturally brings up the question as to whether such clear, light oils, which are found in a very few widely separated places, are condensates or filtrates. Hitherto geologists seem to have been content to treat them as filtrates, assuming that by some unexplained but long-continued process of filtration the heavier asphaltic material and the less volatile components of the ordinary crude oil are removed, only the volatile and lighter fractions passing on. Until lately practically nothing was known to the chemists or physicists which would support such a contention. Lately, however, work on adsorption by silica gels has given remarkable separations, which suggest at least possibilities if not probabilities of facts being disclosed which might explain at least part of the separation of the heavier constituents of the crude oil from the lighter constituents.

A much simpler explanation requiring no assumptions of unknown or unexplored properties of "rock" materials is illustrated by the work just described.

It is recorded in the text books that strata containing crude oil have generally a higher temperature than surrounding rocks which do not contain crude oil. The methane, ethane, and other gases above the crude oil in the sandstone or other porous rock must obviously through long contact, be saturated at that temperature and pressure with the vapours of every volatile constituent of the crude oil, the lighter fractions of course supplying more vapour.

Being gases, they would travel more quickly through the pores of the rock than the liquid. As they left the warmer crude oil centre for the colder rocks, the fall in temperature would result in the condensation of those vapours with which the gas was saturated, until the saturation point had again been reached for each constituent at that temperature. The liquid so deposited would obviously be a clear, light oil practically free from the heavier much less volatile constituents. It would increase in bulk by the dissolving in it to saturation point, at that temperature and pressure, of all the constituents of the gas, including the light vapours.

As the gas can obviously pass for a long way from the main crude oil deposit, it can easily convey from that crude oil much light oil in the form of vapour, and deposit part of that vapour as liquid oil again when and where the temperature falls sufficiently.

This fractional distillation action would explain the fact that oil is sometimes found lighter on the outskirts of an oil deposit. The gas travelling ahead of the crude oil carries the lighter vapours with it, these are condensed by cooling and dilute the crude oil which follows. In such cases the yield of lighter crude oil is followed by the flow of the heavier oil from the centre. When a bore penetrates the main oil deposit such a change in composition would not be noted.

It is not at all unlikely, in the very varying conditions which prevail in the different petroleum deposits, that in some instances filtration or adsorption may be a factor in the creation of deposits of light clear oil.

It seems, however, much more probable that in the great majority of cases it is the condensation of vapours by the cooling of saturated gases which is the main factor. Such condensation may take place in the rocks, or, as in the local case just described, in the bore casing.

The determination of whether a light oil is a filtrate or condensate is of importance to the geologist, as one of the factors to be included in forming an opinion as to the possible or probable distance or direction of the original crude oil deposit from which the light oil has been derived.

APPENDIX

THE EXPERIMENTAL METHODS USED IN OBTAINING THE PROPERTIES OF THE ROMA PETROLEUM GIVEN ABOVE

Fractional Distillation—A 10-litre sample of the oil was taken for fractionation. This was distilled from a 4-gallon copper still through a fractionating column 120 cm long by 4 cm diameter, packed with $\frac{1}{4}$ -inch Lessing Rings. After the first fractionation the fractions were systematically redistilled through the same column. As no breaks occurred in the distillation curve, fractions were separated over 5°C boiling point range. The fractions were redistilled a third and fourth time through a column 115 cm long by 1.8 cm diameter, packed with $\frac{1}{4}$ inch Lessing Rings.

The results of these four distillations, together with a standard A S T M distillation, are shown graphically in Figure 1. Owing to a leakage in the cork at the bottom of the fractionating column, there was 11 per cent loss in distillation 2, as against less than 2 per cent loss in any other distillation. As the leakage was below the column and occurred over nearly the whole range of boiling, it probably did not materially affect the proportions of the various fractions obtained.

As the last three distillations did not show promise of much further material separation, the results of the fourth distillation were taken as suitable for the present purpose. These figures, corrected for losses, are given in Table I of this paper, page 137, 2nd and 3rd columns.

Vapour Pressure of Fractions—Determinations of the vapour pressure of the fractions at temperatures from about 100 to about 180°F were made, and the results are shown in graph form in Figure 2.

The apparatus used is shown diagrammatically in Figure 3. It consisted of two barometer tubes, "A" and "B" 80 cm in length, connected by a U tube to a mercury reservoir "C". The method of closing the top of the tubes is shown in the detail drawing. The barometer tube and a smaller tube "D" were drawn down so as to correspond roughly, and then ground to a tight joint. With mercury placed above the constriction in the barometer tube and the tube "D" seated, there was no leakage of mercury into the barometer after considerable standing, and the air was effectively sealed off. Tube "B" was water-jacketed.

In use the reservoir "C" was raised to the level of the top of the tubes, the plug in "B" removed, and about 1 c.c. of the liquid whose vapour pressure was to be measured was introduced on top of the mercury in "B". This was then lowered and raised so as to rinse out any liquid left from a preceding experiment. After rinsing out thus several times, the mercury level was adjusted so as to enclose about 1 c.c. of the liquid below the valve, which was then closed and sealed with mercury.

On lowering "C" to the level of the bottom of the barometer tubes we now have "A" as a comparison barometer and "B" as a barometer with about 1 c.c. of the liquid floating on top of the mercury. The difference in level between the mercury in "A" and "B" is measured, and is the vapour pressure of the liquid at the observed temperature (subject to corrections described later).

Trouble was experienced with the different fractions owing to their containing dissolved gases which were liberated when in the vacuum of the barometer tube. These of course exert a pressure, and have to be blown out before taking a vapour pressure reading.

When taking a series of readings the apparatus was prepared as above, and boiling water poured through the water jacket, which was closed when full of the hot water. The reservoir "C" and valve were now regulated so as to blow out the gases which had been liberated from the sample in "B". The difference in height between the mercury columns in "A" and "B" was now measured as the temperature of the water jacket slowly fell.

Corrections—The weight of the actual oil in "B" corresponded to less than 1 mm. of mercury pressure and was neglected. The other two important corrections are for surface tension effects and for the expansion of mercury in the heated column, making it lighter than in column "A". The surface tension effect is uncertain, although by no means negligible. As, however, on the bulk of the fractions tested it was less than 5 per cent, no allowance was made. The mercury expansion was corrected for by adding to the vapour pressure measured a quantity equal to $(L \times 0.00818 t)$ where L is the length of the heated column of mercury and t the difference in temperature between "A" and "B". This correction amounted to 5 mm. of mercury for some samples at 180° F. At 100° F. it was only about 1 mm. for all the samples.

The uncorrected vapour pressure results are shown in Figure 2. The corrected pressures used in the calculation are shown in Table I.

The vapour pressure of fractions 1 to 4 were not determined, as they were present in the oil in such small proportions. The fractions above 18 had such small vapour pressures that they could not be satisfactorily determined by the method described.

Accuracy—The apparatus and the method of working were not designed for a high degree of accuracy. Water, with its accurately known vapour pressure, was used for checking the apparatus and method of

working In these control tests with water the greatest variation noted from the recorded standards was 5 per cent With some of the oil fractions the working error would probably be a little greater than with water In the higher fractions where the vapour pressure is only a few millimetres, the working error of this apparatus and method would be appreciably higher than 5 per cent As, however, sufficient information was being obtained from the other fractions, and as considerable time would have had to be spent in getting together and testing the necessary apparatus for the accurate determination of the vapour pressure of these higher fractions without any adequate return from the extra information gained, it was decided to go no further with these determinations Further results obviously could not materially affect the conclusions drawn from these experiments

It is to be remembered that the vapour pressures were not made on a liquid which was a pure definite chemical compound with a constant boiling point, but on a mixture of liquids covering a range of 5°C in boiling points The results obtained in these circumstances must depend somewhat on the manipulation

Vapour Density of Fractions—The method adopted was the modified Duma's method in which the flask containing the vapour is not sealed prior to weighing A narrow tube which was drawn out to a fine tip was sealed to a glass flask of about 120 c.c. capacity The volume of the flask was determined by the weight of water which it contained

In making a determination a volume of about 10 c.c. of the fraction whose vapour density was being determined was introduced into the flask, which was then immersed almost to the top in a glycerine bath at from 20 to 30°C above the boiling point of the liquid When vapour ceased to emerge from the flask it was withdrawn from the bath, quickly cooled, washed, dried, and weighed As air enters the flask when the vapour condenses, there is no necessity to make a buoyancy correction The weight of vapour filling the flask, the temperature and pressure (atmospheric), and the volume of the flask being known, the vapour density is easily calculated

Table I shows the vapour density in pounds per cubic foot at N.T.P. and the corresponding molecular weights of the fractions

Specific Gravity of Fractions—This was determined by the usual method of weighing a plummet in air and then in the liquid The specific gravities are shown in Table I

Figure 1

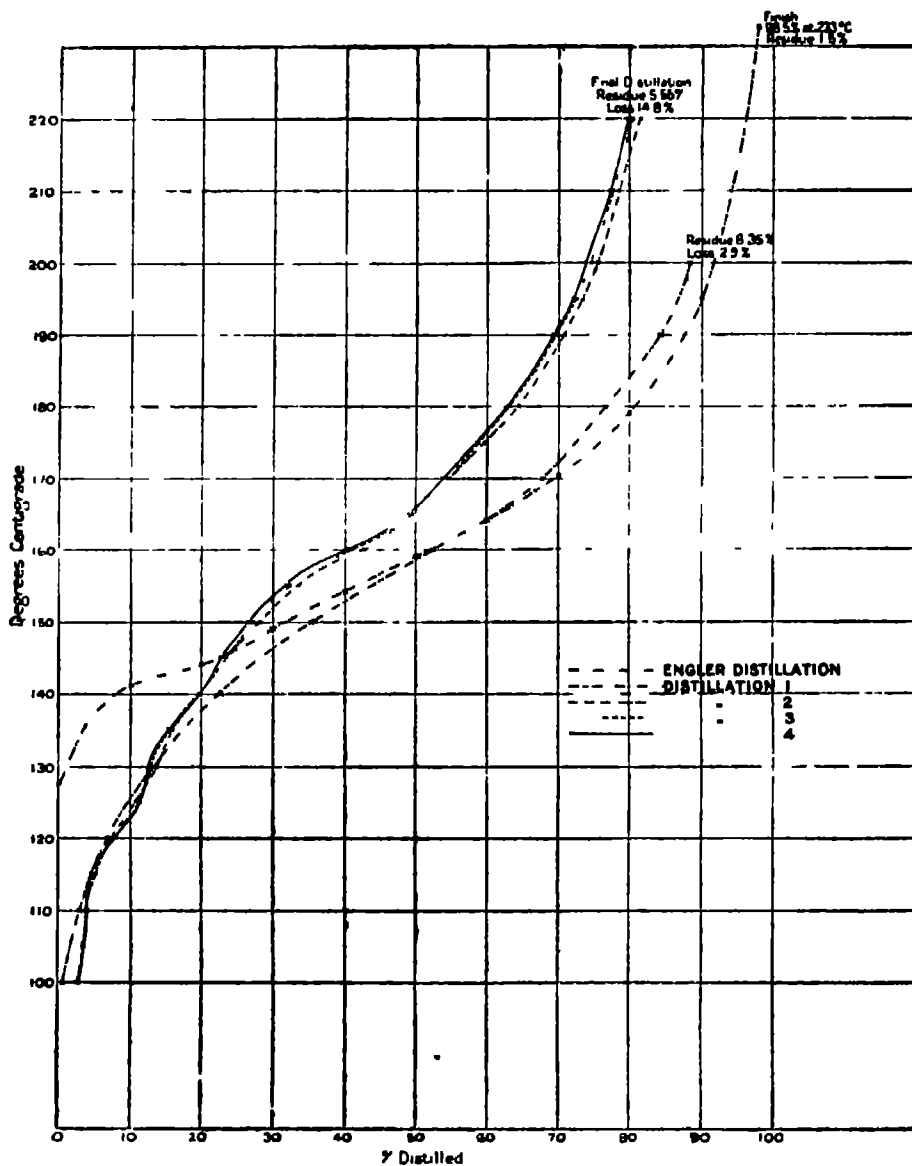
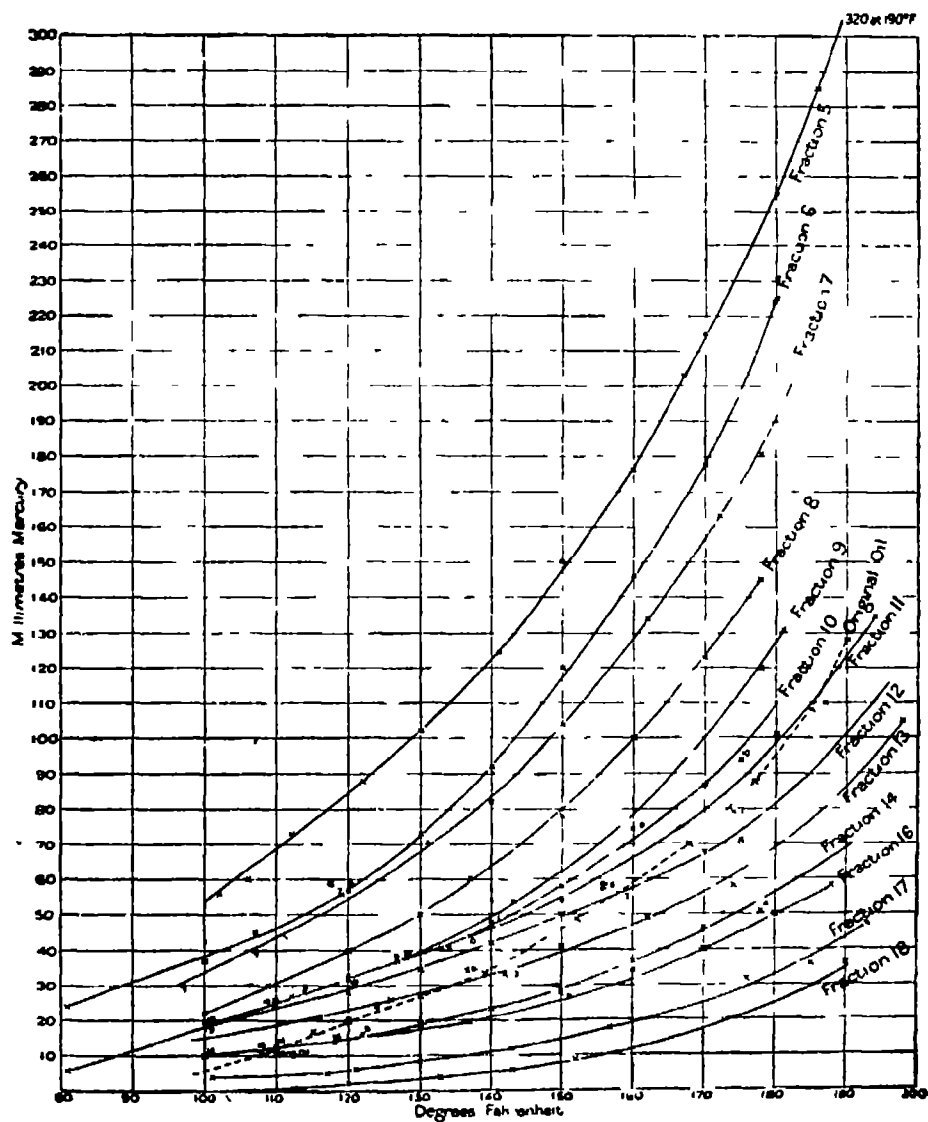
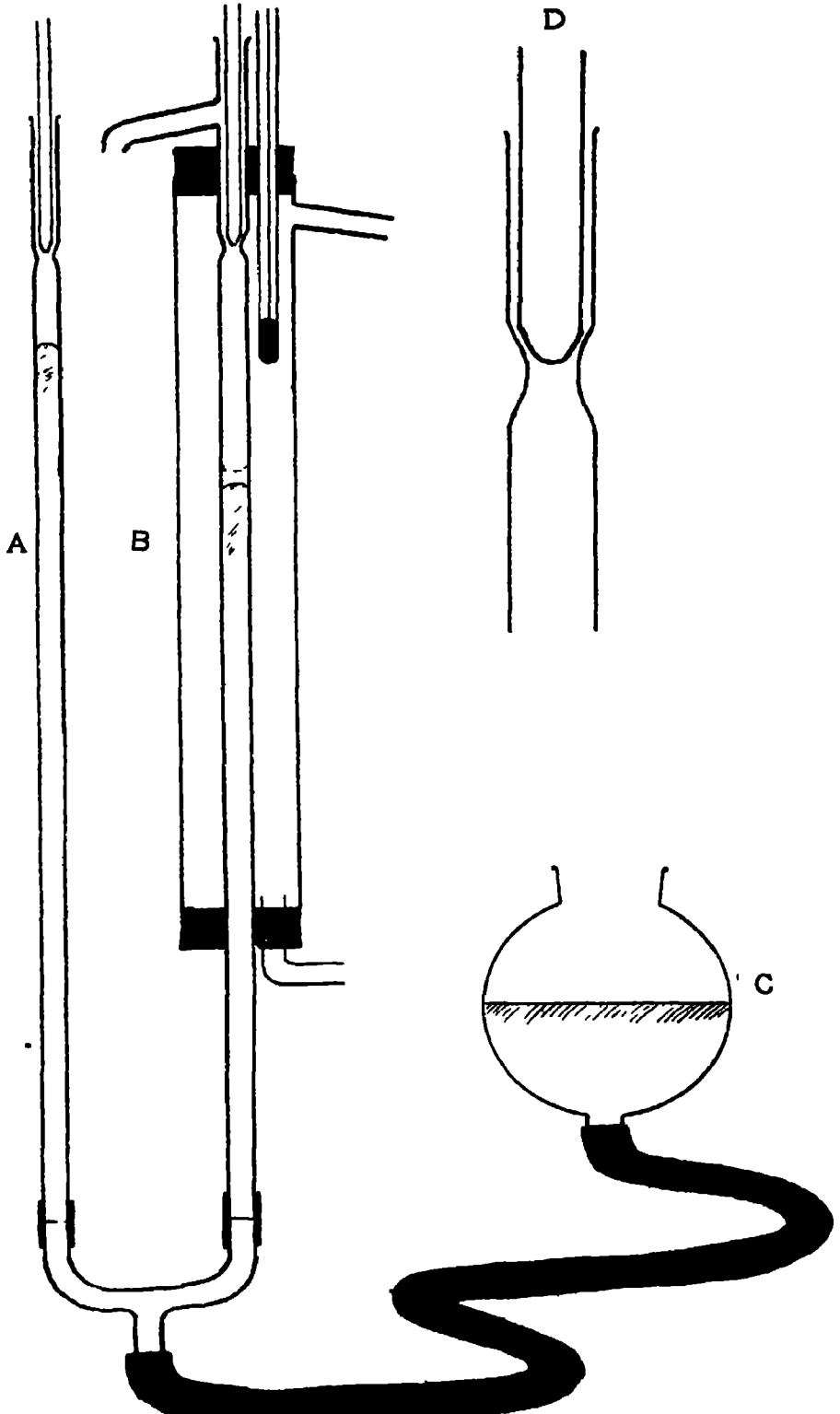


Figure 2—VAPOUR PRESSURES OF FRACTIONAL DISTILLATES OF ROMA OIL
27TH FEBRUARY, 1928





The Brisbane Tuff.

By Mrs C BRIGGS

Plates VIII and IX

(Communicated to the Royal Society of Queensland by Dr W H Bryan,
29th October, 1928)

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I—INTRODUCTION AND PREVIOUS LITERATURE

The Brisbane Tuff is the name given to the rock, composed mainly of pyroclastic material, which occurs at the base of the Ipswich Series of Upper Triassic age in and around Brisbane

Several references have been made to it by earlier workers but the majority of these do not describe it in any detail but merely note its existence

The earliest reference to what we now know as the Brisbane Tuff was made by J S Wilson¹ in 1856 in his "Notes on the Geology of the Neighbourhood of Sydney, Newcastle and Brisbane" in which he wrote "Traversing the town of Brisbane, there is a large dyke [sic] of flesh-coloured porphyry, containing crystals of quartz and felspar and many fragments of the slate rock through which it has been erupted. These fragments show no indication of having been fused or altered. The dyke is 200 ft thick, it rises up between the slates and is parallel to them in direction and dip"

W H Rands,² in 1887, in his report accompanying the geological map of the city of Brisbane and environment referred to the occurrence of a rock running north and south through Brisbane. This, as we have seen, had formerly been regarded as a porphyry, but Rands after a study of its megascopic characters definitely classed it as a volcanic ash. He also referred to its stratigraphical position at the base of the Ipswich Measures and to its use as a building stone

¹ Q J G S, vol. xii, 1856, p. 288

² Rands's Report accompanying the Geological Map of Brisbane Geol. Surv. Qld. Publ. No. 34, 1887, p. 1

In 1888 Dr R L Jack,⁴ in his paper "On Some Salient Points in the Geology of Queensland," notes the outcrop of a series of "ashy sandstones" at the base of the Ipswich Coal Measures containing carbonised and silicified wood, to be seen in Brisbane resting unconformably on the Brisbane Schists. The same writer⁴ in 1892 added that at Ann street, Brisbane the rock dips at 18 deg and is separated by 31 in of light and dark coloured shale from the older micaceous schists which the shales overlie unconformably.

Dr E O Marks in 1911⁵ published a paper on the "Coal Measures of South east Moreton." In this he stated that a bore was put down at Mona Park through 27½ ft of tuff, and was overlain by shale at a depth of 470 ft. He stated further that "the occurrence of volcanic tuff in the bore at Mona Park is thus of more than mere geological interest for tuff is known to be at the base or near the base of the Coal Measures and it now seems probable that it extends beneath the system over the whole area between Logan Village and Brisbane." The Coal Measures of the Broadwater, Tingalpa area, and of the coastal area of South east Moreton are generally associated with tuff. Accompanying Marks's report is the most recent geological map of Brisbane.

In his paper on the Volcanic Rocks of South eastern Queensland Professor Richards⁶ gave a concise petrological description of the Brisbane Tuff.

Dr A B Walkom, in 1918,⁷ in his "Geology of the Lower Mesozoic Rocks of Queensland," referred to the Brisbane Tuff as "a rock probably of volcanic origin although there is no indication of its source, resulting from the deposition of volcanic ash of an acid nature over a long narrow area in the vicinity of Brisbane."

The most detailed description of the Brisbane Tuff is to be found in Professor H C Richards's⁸ paper on "The Building Stones of Queensland," published in 1918, which deals briefly with its megascopic and microscopic characters, and at considerable length with its value as a building stone.

Mr B Dunstan, in 1920,⁹ in an introduction to Sahni's paper on "Petrified Plant Remains of the Queensland Mesozoic and Tertiary Formations," gave a short account of the stratigraphical position of the tuff, and remarked on the great abundance of the petrified woods and the position which they occupy relative to the tuff.

Mr C C Morton, in 1922,¹⁰ in an article on "The Coal Prospects of the Narangba District," noted that in Portion 30 of the Parish of Whiteside

⁴ "On Some Salient Points in the Geology of Queensland," p 8

⁵ "Geology and Palaeontology of Queensland and New Guinea," by Jack and Etheridge, p 321

⁶ "Coal Measures of South east Moreton," Qld Geol Surv Pub No 225, p 15

⁷ P R S Q 1918, p 145

⁸ Proc Linn Soc NSW 1918, p 48

⁹ P R S Q 1918, p 137

¹⁰ Geol Surv Qld Publ No 267, p 1

¹¹ Qld. Govt Mining Jour May 1922, p 4

there is an extensive exposure of the rhyolite agglomerate and tuff which thereabouts forms the base of the Coal Measures and is probably the equivalent of the Brisbane Tuff

Mr O A Jones,¹¹ in the appendix to his paper on "The Tertiary Deposits of the Moreton District," has described a volcanic tuff which in thin section closely resembles the Brisbane Tuff although in the hand specimen the rock resembles that found in the Chermside and Aspley districts more closely than the typical rock found nearer to Brisbane itself

This tuff, which outcrops at Mount Crosby is only about 4 ft thick and grades into a compact tuffaceous shale, but it appears to occupy the same position relative to the Ipswich beds as the tuff does in Brisbane

In 1927 Professor H C Richards and Dr W H Bryan published a paper on ' Volcanic Mud Balls from the Brisbane Tuff ' ¹² The outcrop described was at Castra, on the right bank of Tingalpa Creek, about 12 miles ESE of Brisbane Since the publication of this paper several specimens very similar to those obtained from this outcrop have been found at Aspley

II—FIELD OCCURRENCE

The Brisbane Tuff, as previously stated, outcrops within the city of Brisbane itself, and most of the previous references include results which have been based on a study of these outcrops, that at the intersection of Ann and Gotha streets in particular having attracted the attention of several geologists

It was not until Marks connected up the isolated outcrops in 1911 that the extent of the series was indicated His map shows that with one exception all the outcrops are confined within an area of 80 square miles Since then the tuff has been found in several other localities

The main outcrop extends for about 15 miles in a direction N 30° W It has been traced continuously in a northerly direction as far as Aspley, where its boundary becomes indefinite owing to the presence of overlying alluvial material Further north it occurs as a few isolated outcrops, the most northerly of which is at Narangba, which is 4 miles from Aspley Passing southward through Brisbane the main outcrop bifurcates, the southern limit of the western leg being at St Lucia and that of the eastern at Coorparoo

The width of outcrop is at its greatest about $\frac{1}{2}$ mile, but is throughout most of its length considerably less than this In the vicinity of its greatest width, the greatest vertical section (about 100 ft) is exposed But this is not a maximum thickness, for the base in most cases is not shown Thus the cliffs at Kangaroo Point, composed wholly of tuff, are about 100 ft high, but the line of junction with the Brisbane Schist is out of sight and below the level of the Brisbane River Above Collin's wharves and at Leichhardt street and in several of the quarries good vertical sections of

¹¹ Proc Roy Soc Qld 1926, p 43

¹² Proc Roy Soc Qld 1927, p 54

the material can be seen, but except in a few cases, as at Campbell's Quarry (Albion), Boggo road, Belmont, and Gotha street, the junction is not above the surface. In a few localities the dip and width of outcrop are known and the thickness may be calculated. For instance, at Belmont the width of outcrop on either side of an anticline can be seen and this gives a total thickness of about 300 ft. At Boggo road the thickness has been determined as approximately 160 ft.

In the main outcrop there are one or two sections which show clearly the relationship which exists between the tuff and the associated beds. A vertical section at Ann street¹³ showed the following conformable succession from the bottom —

- (1) A few feet of carbonaceous shale,
- (2) A hardened band of tuffaceous material about 1 ft 6 in in thickness,
- (3) The main mass of the tuff about 15 ft in thickness covered by a thin layer of soil, the whole resting unconformably on the Brisbane Schist.

Near the Children's Hospital is to be seen a similar section to that at Ann street, differing from it only by the presence of a conglomerate in place of the basal shales.

Walking across the beds on Boggo road the following succession is passed over —

- (1) Brisbane Schist,
- (2) A few feet of shale containing fossil wood
- (3) True tuff, which is here highly silicified,
- (4) A series of very striking conglomerates containing huge boulders of quartzite,
- (5) Tuffaceous sandstones and shales.

This occurrence of fossil wood between the Brisbane Schists and the shales is very characteristic and as Mr Dunstan pointed out, serves as an indication of proximity to the junction line between the Brisbane Schist and the Brisbane Tuff. When present, the conglomerate mentioned above serves a similar purpose for the determination of the upper limit. Unfortunately this is not always present and the lithological change is often so gradual that it is very difficult to make any line of demarcation as to the upper limit of the tuff.

A small section which shows how the tuff may thin out between the Brisbane Schist and the Ipswich Coal Measures is to be seen in Campbell's Quarry at Albion. Here the schist forms the base. Above this are a few feet of very much altered tuff, and resting on this again are the Ipswich Measures. Nowhere is the dip of the tuff very steep, this being an indication that very little movement has taken place since the material was laid down. The maximum dip so far determined is about 20°. Although the tuff is

¹³ This section is no longer exposed.

conformable with the shales below and above it, and was probably laid down under similar conditions, it shows little evidence of stratification

Although the above remarks refer to the main outcrop only, they are generally applicable to the whole area. An outcrop which may be regarded as a continuation of the main mass occurs at Tarrigindi. Its exact extent is difficult to determine owing to the presence of alluvial material which covers a considerable portion of the area. Of the other outcrops that which runs through Belmont in a direction similar to that of the main mass is the largest. The material found here is similar to the white tuff found at Collin's wharves. About a mile to the east of Belmont are two outcrops with their greatest length in a direction at right angles to the two main outcrops. About 9 miles to the south of these and in a direct line with them is a very small area of tuff at Loganlea. Although there is no tuff on the surface between the latter and former outcrops, it is quite likely that it occurs below the ground-level over quite a large part of the area. Boreholes have been put down at Mona Park and tuff has been found between the Brisbane Schist and the Ipswich Measures at a depth of over 400 ft. A further small isolated outcrop occurs at Castra. Near Morningside there is a small outcrop of the characteristic tuffaceous material in the nature of an inlier within the Ipswich Measures. In the railway cutting a few yards from the quarry a definite junction between the Brisbane Schist and the Ipswich Coal Measures can be seen, the tuff being present only in the form of boulders in the conglomerate. The thickness of the tuff here is evidently not very great, as the quarrymen report having found shales at no great depth below the present road-level.

To the south of this there is an outcrop near White's Hill. The material here is not as characteristic as that at Morningside and its exact extent is not determinable.

III—PETROLOGICAL CHARACTERS

(A) MEGASCOPIC CHARACTERS

The Brisbane Tuff is a truly fragmental rock, being composed of tuffaceous material of an acidic nature with included rock fragments.

(a) *Arrangement and Nature of Inclusions*

There does not appear to be a persistent regularity in the arrangement of inclusions. In some cases there is no definite arrangement, while in others there is a distinct tendency towards parallelism. The latter is often exhibited by the soft, powdery spots which occur in the pink variety, reference to which will be made later. A linear arrangement of small drusy cavities into which small quartz crystals have grown is noticed in some of the material from Bowser and Lever's quarry at O'Connelltown. These represent replaced fragments of schist.

Fragments of igneous rock can sometimes be seen in the hand specimen, but it is often difficult to determine whether this material is really a foreign inclusion or part of the original igneous mass. Those inclusions which are seen are of an acid nature, quartz and felspar being the only determinable

minerals. These have the same characteristics as those in the ground-mass, but the felspar is sometimes more weathered.

One or two specimens show inclusions of a dark-green rock which is apparently igneous in nature and in which decomposed felspars are abundant.

The fragments of schist owing to their dark colour and typical cleavage are easily distinguished. They generally resemble the local schist very closely and usually show no evidence of being waterworn. In some cases they have been altered subsequent to inclusion to a sericitic mass, and as indicated above have sometimes been replaced by silica. The slate inclusion from Morningside may be a variant of the schist, and like the schist no minerals can be distinguished. The inclusions vary largely in size, although in the city itself they are remarkably small and of fairly even size. At Morningside they are much larger, the greatest being about 5 in. square, and at Bowser and Lever's quarry at O'Connelltown some fragments approximate to this size. A very common inclusion is that of small fragments of chert which as a rule measure only approximately $\frac{1}{4}$ in. in diameter. Occasionally larger fragments are found at Windsor, where the largest seen was about 5 in. in diameter.

Minerals Present—

These may be considered under two headings—

- (1) Those which can be determined in the fragments.
- (2) Those which belong to the ashy material.

In dealing with the former a short account of the nature of the inclusions themselves will be given.

As the rock is composed mainly of ashy material one would not expect to find many minerals in crystalline form, the only recognisable individual minerals being quartz and felspar.

Quartz—This is generally in the form of blebs which never exceed $\frac{1}{16}$ in. in diameter, and are characterised by their translucency and freshness.

Felspar—The felspar on the other hand generally occurs in elongate crystals, white in colour, opaque and very often much altered to a pale-green decomposition product and kaolin.

The presence of iron is indicated only by limonite stainings most probably of foreign origin.

(b) Bedding and Stratification

The most characteristic feature of the tuff is its uniformity and lack of bedding. The compact character of the series as a whole seems to have been induced for the most part by the deposition of siliceous material from percolating solutions, which may have had the same origin as the tuffaceous material itself. The general uniformity of silicification does not suggest injection but rather downward percolation of such solutions. There seems to be an increase in silicification as we pass northward from Brisbane, but no such generalisation can be made regarding any other part of the outcrop.

In some cases, as at Leichhardt street, silicification has increased with depth. Here may be mentioned a more highly siliceous and compact band of material varying from about 2 ft to a few inches in thickness, lying at the very base of the tuff. This band is sharply differentiated from the rest of the tuff, so much so that it has been thought by some to represent not a tuff but a rhyolite flow. It differs further from the material above in not containing fragments of schist, fossil remains, or carbonaceous material in any quantity. Its occurrence as a thin sheet fairly uniform in thickness does suggest a rhyolite flow, but on the other hand the absence of fluxion structure and the marked similarity in microscopic structure to the overlying material suggests that it is truly tuffaceous material which has become hardened by the percolation of siliceous solutions.

Professor Richards¹⁴ in speaking of this particular band says: "It is noticeable however that this band is best developed when the overlying tuff is most silicified and it is highly probable that it represents a layer of tuff at the bottom which has received an extra amount of silicification owing to the percolating solutions being held up by the impervious underlying shale band." In some cases small bands of this silicified material give an appearance of stratification, but these are probably veins or cracks which have been filled up with the siliceous material or parts of the rock in which replacement has taken place.

Again, it has been noted in a few instances that in the upper levels of the tuff a banding is induced by weathering. The marked character and regularity of this, particularly in one specimen, gives the rock a stratified appearance. This was found at Kangaroo Point, although probably not *in situ* as it differs considerably from the typical rock of this locality. The bands, which are roughly parallel, vary in width from $\frac{1}{16}$ in to 2 in and in colour from pale mauve to deep purple.

Colour—There is great variety in colour, although perhaps pink is predominant; white, grey, green, brown, and all shades of purple also occur, the colour varying with the amount of iron and manganese oxides present and their state of oxidation. No one variety is confined necessarily to any one area, for in most cases we find two or more colours in close proximity to one another. The colour is generally evenly distributed throughout the specimen itself, except in the case where limonite stainings are present.

The colour of the rock is of great importance, since it serves as an indication of its weathering properties. The pink and white varieties appear to be the most stable, but some of the pink material has a series of soft white powdery spots, the larger of which seem to have a tendency towards parallelism. These may represent weathered inclusions, but their outline seems in most cases to be rather indefinite, and in no case has a transition stage between an inclusion and the powdery material been observed.

¹⁴ Proc Roy Soc Qld 1916, p 146

Further, small siliceous particles resembling those of the main mass are generally found in the powder. It seems more likely that these patches are the result of differential weathering of the tuff itself. The more silicified material is generally white and more stable on account of its low iron percentage. As the silicification has been rather irregular, such white tuff is somewhat confined in different areas. The grey tuff is limited to the highly siliceous band at the base of the series.

Brown colouring, except as a surface coating, is found only in very weathered material. The green tuffs as a rule weather badly, the paler green varieties decomposing into a whitish shaly material which slakes easily. On the darker green varieties a dark coating forms which seems to protect them from further decomposition. This may be seen in progress in the O'Connelltown and Windsor quarries, particularly in the former.

(b) *Microscopic Characters*

After the microscopic examination of slides from various localities one is struck by the uniformity of the tuff in texture and composition. With the exception perhaps of the material from Boggo road, and the lower siliceous band, the sections differ very little. The following description is given as the result of the study of some twenty-four slides made from rock taken from the more important outcrops. The typical tuff is seen to be composed of a light brown base which generally appears very much altered and is for the most part isotropic. In this are set crystals of quartz and felspar, and inclusions of foreign rock material the character of which can generally be determined.

The original glassy structure can often be seen, and is particularly well developed in some of the sections of material taken from Bowser and Lever's quarry at Morningside. This warrants Pirsson's name "Vitric Tuff" being applied to this rock. Some of the inclusions show a linear arrangement.

The structures within the inclusions are not always easy to detect. The schistose structure so easily seen in the hand specimen cannot be determined under the microscope. In some of the igneous rocks a structure resembling microporthus is developed. As the character of the quartz and felspar in both the base and the inclusions appear to be the same, a detailed description of them will be given when discussing the fragments of igneous rocks. There is a complete absence of ferro-magnesian minerals, the presence of iron being indicated only by limonite staining, which in some cases may be derived from a foreign source.

Schists—These are only very small and the only basis for terming the majority of the schists is their shape and colour. They are generally dark in colour and more or less elongate.

Cherts, Quartzite, etc—Some of the sections show numerous black, opaque fragments which may possibly be charcoal, but more probably represent foreign rock material such as cherts, quartzites, etc.

Igneous Rock—

These are abundant, and seem to consist of quartz and felspar which are sometimes set in a glassy base

Quartz—This is generally very fresh, often with numerous inclusions of felspar other minerals too small to be distinguished, and air bubbles. The crystals are often very much corroded. Except where corrosion has taken place the outline is sharp most of the fragments being triangular in shape. These fragments vary in size but the largest does not measure more than one millimetre across. A striking feature of the quartz is the absence of cracks.

Felspar—There are at least two varieties of felspar present.

Orthoclase occurs in roughly rectangular crystals generally with one well-developed cleavage and always highly decomposed, alteration taking place along the cleavage lines. This often gives the effect of intergrowth when the section is placed between crossed nicols. The alteration seems to be mostly to kaolin, there being no trace whatever of secondary mica in any of the slides. A characteristic of this felspar is the comparative absence of twinning. This may be only apparent, as the twinning could be easily masked by alteration. Some of the fresher crystals show simple twinning.

Very few inclusions are seen, but these again may be easily masked by alteration. Micrographic intergrowth of quartz and felspar occur, a very good example of which is seen in a section taken from Morningside. There does not appear to be any orientation arrangement of the long axes of the crystals. There is present in much smaller quantities a felspar showing multiple twinning, which has an extinction angle, corresponding to that of *Andesine*. One or two felspars seem to show a continuation of Albite and Pericline twinning, but as the crystals themselves are so small and the twinning itself is on such a small scale it is difficult to state whether this is microcline or one of the Plagioclase series. These felspars, too, show various degrees of alteration. There are no other distinguishable minerals present in these inclusions, and the complete absence of ferro-magnesian minerals suggests that the rock is derived from material of a very acidic nature.

The rock is commonly known as "porphyry" and has at different times been referred to as an "ashy sandstone," "trachytic tuff," and latterly as a "rhyolitic tuff." Its pyroclastic nature was recognised by W. H. Rands as early as 1887.

The chemical analysis as determined by Mr. G. R. Patten, of the Agricultural Chemists' Laboratory, shows that the rock is decidedly acid in nature and most closely resembles some of the Tertiary Rhyolites of South eastern Queensland.

In the light of a combined megascopic and microscopic study, the rock then merits the name "Rhyolitic Tuff."

IV—CHEMICAL CHARACTERS

COMPARISON OF ANALYSIS OF BRISBANE TUFF (1-3) WITH OTHER LOCAL IGNEOUS ROCKS (4-8) AND WITH THE WORLD'S AVERAGE RHYOLITE (9)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
SiO ₂	75.52			73.52	71.50	61.10	77.15	74.28	72.02
Al ₂ O ₃	12.73			11.05	14.13	19.24	13.45	11.27	13.77
Fe ₂ O ₃	2.18			Nil	0.60	1.24	0.40	1.93	1.29
FeO	1.43			3.15	3.23	3.42	1.26	0.58	0.90
MgO	0.27			1.03	1.17	2.58	0.72	0.44	0.38
CaO	0.28			1.70	2.70	5.25	1.22	1.15	1.43
Na ₂ O	2.30	0.76	0.34	4.08	2.97	3.82	2.72	2.74	5.55
K ₂ O	1.47	1.85	2.68	3.99	2.80	1.68	3.76	4.77	1.09
H ₂ O	1.20			0.44	0.32	1.31	0.20	1.01	1.53
H ₂ O	0.48			0.18	0.10	0.64	0.08	0.70	
TiO ₂	0.30			0.20	0.41			0.25	
P ₂ O ₅	0.16			0.15	0.35		0.10	0.07	
MnO	0.01				0		0.32	0.02	0.12
	100.57			99.47	100.36	100.26	101.38	99.21	99.68

(1) Brisbane Tuff, Howser and Lever's Quarry

(2) Alkali content of Tuff obtained from Collin's Wharves

(3) Alkali content of hard band of Tuff at base of cliff at Collin's Wharves

(4) Typical Pink phase Enoggera Granite

(5) Enoggera Building Stone

(6) Typical Grey phase Enoggera Granite

(7) Granite, Stanthorpe

(8) Rhyolite, Esk

(9) Average Rhyolite, Daly

The first three analyses were carried out by Mr Patten, of the Queensland Agricultural Chemists' Laboratory. The others have been added to the list for the purposes of comparison.

The analysis of the Brisbane Tuff shows a very high silica percentage, thus the rock is distinctly acid in nature. The iron percentage is exceptionally high for an acid rock, but part of this has probably been derived from the foreign material present. The variation in the alkali content, as shown by the three analyses made, is very striking. The tuff from which the analysis was made at Collin's wharf is decidedly more siliceous than the average material, but that would not altogether account for the extremely low alkali content.

Except that they all have a high silica percentage, they do not resemble the analyses of the granites from Enoggera very closely, but they may better be compared with that from Stanthorpe. Here the alkali contents more closely correspond, and while the iron is higher in the tuff the silica is slightly higher in the granite.

Analyses of rhyolite from Esk and of the average rhyolite composition as determined by Daly show that the rock resembles these more closely than the granites of the Brisbane district.

V—INCLUDED PLANT REMAINS

Fossil wood is very plentiful in the shales immediately below the tuff, but it seems that there is not a great abundance actually included in the tuff.

(1) At Morningside an equisetaceous stem fragment about 9 in long showing eight nodes and seven complete internodes was found. The internodes vary in length from 7 in to 12 in. Some of the wood has been preserved, but after exposure to the air this is rapidly decomposing to form a brown powder, and therefore cannot be easily handled. Where striations can be seen they appear to be continuous through at least two adjacent nodes. On account of its fragmental nature an exact determination of the genus cannot be made. It certainly belongs to the family of Equisetales, and may be *Phyllothea* or *Schizoneura*, the latter of which is more commonly found in the Lower Mesozoic strata of Queensland.

This fossil, which has been exhibited at a previous meeting of the Royal Society, is preserved in a highly silicified tuff.

(2) At the Windsor Council quarry there has been unearthed a charred tree trunk. This material shows the typical wood structure, particularly on heating in the air, when it turns white.

In the University of Queensland Geological Museum there are specimens showing fragments of charcoal and silicified wood actually included in the tuff.

In several cases wood has been found in close proximity to weathered tuff, and it seems quite likely that in some instances such has originally been included in the tuff. Such fossil woods as are found *in situ* occur near the base. Those tree trunks and limbs which have been found both in the tuff and underlying shales seem to lie with their long axes approximately horizontal.

Sahn described and named several fossil woods sent to him from South-eastern Queensland, but the only one of these belonging to the Triassic is *Cedroxylon brisbanense*, which was found near Boggo road. The detailed description of this may be seen in Sahn's paper already cited.

VI—AGE AND ORIGIN

AGE OF THE TUFF

The conformity which exists everywhere between the Brisbane Tuff and the Ipswich Series indicates that there has been practically no time-break between their deposition.

There are many sections which show this relationship between the tuff and the rocks below it, but that at Ann street is worthy of special mention.

The fossil evidence is not sufficient to assist in the exact determination of the age of the Brisbane Tuff, and the field evidence thus indicates that the material which formed the tuff was extruded not later than late Triassic and not earlier than earlier Triassic times.

ORIGIN

That the material is of a volcanic nature has already been established. The problem of origin and mode of deposition, however, is one not easily

solved, evidence being rather insufficient and in some instances confusing. Nevertheless, there are a few significant facts which may assist in the final solution of the problem.

(1) There is a marked uniformity in the size of the inclusions and in the nature of the ash itself. The former are generally small, the only localities where fragments over $\frac{1}{2}$ inch in length have been found being at Morningrude, Windsor, and O'Connelltown, where the largest was only 5 in square. These larger inclusions occur near the base of the tuff. It is significant that where the lower more siliceous band occurs it is particularly free from inclusions of schist, although slaty cherty and rhyolitic fragments are fairly common. These, however, are small and generally rounded or subangular.

(2) Mr Dunstan¹⁵ states that 'volcanic outbursts at the beginning of the Triassic formed a very thick deposit of dust and ash over the valleys and hills of the Brisbane district, and the timbers growing on the shale and the schists at that time were enveloped and destroyed by a great thickness of this dust. The deposits were evidently not laid down as mud, as the tops of the hills were as thickly covered as the bottoms of the valleys, while in addition fragments of charcoal at the base of the tuffs, quite unchanged even after such a length of time give evidence of the burning of some of the timber while its envelopment was taking place. The exterior portion of the trunks of the trees which have been charred by fire have not been fossilised, but, where the wood has not been burnt and evidently covered over while green, the hot percolating waters carrying in solution silica derived from the minerals in the volcanic ejectamenta have subsequently silicified the cells of the wood.'

It may be significant that charcoal and fossil woods do not occur in the lower more highly silicified band of rock, and that where they do occur in the main mass of the rock the lower band is conspicuously absent.

(3) The shape and direction of the outcrops might lead one to suppose that the tuff was laid down in what constituted the valleys of Triassic time. If the suggestion of E. O. Marks, that the tuff had practically the same distribution as the Ipswich Measures in this area, is correct, the shape of the outcrop would be of no significance. Evidence from the bores which have been put down tend to support the suggestion, but these lie on the same line as the main outcrop, so that such evidence is not conclusive.

There is no direct indication of the centre of eruption of this tuffaceous material within a reasonable distance of its outcrops. The uniformity of the material suggests that the source of origin was approximately at the same distance from all points on the outcrops. This, together with the fineness of the material and the absence of coarse volcanic ejectamenta, would suggest that the source was not very close to the present outcrops. Certainly the material was not transported any distance by water, for the included fragments are angular, there being a conspicuous absence of rounded pebbles in the main mass of the material. At the same time some

¹⁵ Introduction to Sahni's paper, Geol. Surv. Qld. Publ. No. 267, p. 5

of the cherty and rhyolitic inclusions found in the more highly silicified "lower band" are distinctly rounded and subangular.

We know that in Triassic times there was an extension of the present land mass to the east, and as there is no trace of a centre on the land at the present it might be assumed that the centre is now below sea-level.

The association of the "lower band" with the underlying shales favours the suggestion that it was laid down under water. The absence of large fragments and the rounded character of the cherty rhyolitic inclusions is also in favour of such a suggestion.

It has been stressed above that charcoal or fossil wood in the tuff is not particularly abundant, and that its occurrence is rather local. The presence of fossil wood in quantity in the underlying shale is evidence of a heavily wooded land surface. If the tuff were deposited wholly on such a surface it seems that fossil wood or charcoal would be much more abundant than it actually is, and that there would be much more evidence of fossilisation and charring *in situ* than is obvious. Most of the charred wood actually in the tuff is fragmental, and where trunks or limbs occur these are always in a prone position.

From the evidence it seems that the tuff was laid down on land surface, the continuity of which was broken by a series of small freshwater lakes. These may have represented the youthful stage of the lake system in which the Ipswich Measures were subsequently deposited. In them possibly the more highly silicified tuff was deposited contemporaneously with that deposited on the land surface, and that the silica-charged water subsequently caused the extra silicification.

VII—RELATIONSHIP TO OTHER IGNEOUS ROCKS

In general there seems to have been a dearth of volcanic activity during the Triassic period, but the late Palaeozoic era was characterised by worldwide movements and intrusions on a very large scale, which latter are represented in South-eastern Queensland by the granitic masses at Stanthorpe and Enoggera, etc. Subsequent to these were intruded a series of dykes which may be seen in and around Brisbane, especially in the immediate vicinity of the Enoggera mass. The Stanthorpe and Enoggera masses were intruded probably at the close of the Palaeozoic or at the latest in the early Mesozoic era, and were followed by the deposition of a series of volcanic tuffs probably in late Triassic times. Is there any genetic relationship between the Brisbane Tuff and the earlier intrusions?

For some years there has been a general belief that there may be some such connection. Thus¹⁶ Mr L. C. Ball, in his "Notes on Indooroopilly," stated that "if the Brisbane Trachytic tuff could be connected with the dyke at Indooroopilly we might be in a position to decide on the period in which deposition took place, but the necessary petrological work has not yet been done."

The facts that no source of the tuff can be found, that the granite, rhyolitic dykes, and tuff are similar in chemical composition in that they

¹⁶ Qld Govt Min Jnl 1920, p. 266

are all acid and that they occur in somewhat close proximity to one another, would lead one to seek a connection between them. Inclusions of rhyolitic material very similar to that of the dykes are found in the tuff, but there is no trace of any fragments of the granitic series.

Some of the aplitic dyke material resembles the more highly silicified tuff very closely in appearance. When examined under the microscope the rhyolitic inclusions resemble very closely the true dyke material, although the actual feldspars present in the latter have not yet been determined.

It is interesting to note that andesine is the only plagioclase feldspar which has been determined in the tuff, and Dr Brvan states that andesine is very plentiful in the grey phase (hybrid rock) of the Enoggera Granite series.

A consideration of all the evidence points to the following chronological order of the rocks in the Brisbane district —

Upper Triassic	{	Lacustrine Deposits	Coal Measures
		Pyroclastic Sediments	Tuff
		Lacustrine Deposits	Shales and Conglomerates
Late Palaeozoic	{	Hypabyssal Intrusions	{ Porphyritic Series
			{ Rhyolitic Series
		Plutonic Intrusions	Enoggera Granite

It has been proved that there are generally three distinct phases of igneous action, their respective characteristics being (1) volcanic extrusions followed by (2) large plutonic intrusions, which in turn are followed by (3) minor intrusions. But Harker¹⁷ points out that "there has been in several past periods a final reversion to the extrusive phase of action following what we have regarded as the normal cycle of earth movements and divided from it by a considerable interval of time. This recrudescence of vulcanicity has always been relatively feeble and has operated within a much restricted area or broken out in a few isolated centres." In South-east Queensland these phases may all be recognised, but the earliest extrusive phase (which may be represented by the volcanic Permo-Carboniferous rocks of the Silverwood district) is absent in the Brisbane area. The above chronological table shows the Enoggera granite, representing the large intrusive phases and the dykes of porphyritic and rhyolitic material, as the representative of the third phase. Separated from these by a considerable space of time there is the Brisbane Tuff, which may perhaps be regarded as the result of this later smaller phase of volcanic action.

Professor Sir Edgeworth David says "In New South Wales there is a considerable development of more or less fine volcanic tuff in the lower division of the Triassic known as the Narabeen stage. These tuffs are distinctly basic in character and like the lava of the Permo-Carboniferous contain metallic copper. Through redistribution in water the tuffs have passed into the characteristic chocolate shales so well known at Long Reef

¹⁷ Harker, 'Natural History of Igneous Rocks'

and Narabeen " But these rocks are very different in character from the Brisbane Tuff. Indeed, the Brisbane Tuff resembles more closely in both megascopic and microscopic characters some of the Tertiary volcanic ashes

Since volcanic activity in Triassic times throughout the world was comparatively rare, the Brisbane Tuff attains an added interest and importance

VIII—ECONOMIC VALUE

It was not long before the residents of Brisbane realised the economic value of the Brisbane Tuff, commonly known to them as porphyry, for as early as 1855 it was used in the building now known as Rosemount Hospital. Since that time it has been used locally on an extensive scale for building stone and other purposes. As has been stated previously, the rock varies greatly even within very restricted areas, the specific gravity ranging from 1.92 to 2.27 and absorption from 4.25 to 11.75 per cent. The tuff although not always well jointed is not difficult to work. Apart from its use as a building stone it has been used for kerbstones, road metal, and the finer material for footpath and tennis court dressings.

Dr H. C. Richards in the "Building Stones of Queensland" deals fully¹⁸ with the value of this rock for building purposes. As a building stone the tuff may be used to advantage, provided it is carefully selected, and not placed in a position where it is subjected to the continuous action of moisture or to great pressure.

The more compact and silicified the tuff, other factors being equal, the better it is as a building stone. Most of this material, which is used in the buildings of Brisbane, comes from the quarries at O'Connelltown and at Leichhardt street. It has been silicified to a moderate extent, and the inclusions which give the tuff at Kangaroo Point such a weathered appearance are practically absent in the stone at O'Connelltown. As in most building stones, the undressed stone weathers better than the dressed material.

The great advantage of the rock for all the purposes mentioned above is its easy accessibility and consequent low cost, none of the quarries being more than a few miles distant from the city.

LIST OF BUILDINGS WHERE THE TUFF HAS BEEN USED

Rosemount Hospital (1855)
 Normal School (1863), Spring Hill
 Base of the G. P. O. (1871-1874)
 St. Stephen's Cathedral (1874)
 St. Paul's Presbyterian Church (1887), Spring Hill and O'Connelltown
 St. John's Cathedral (1909-1911), O'Connelltown
 Base of the Government Printing Office, 1912
 Police Commissioner's Office
 First three courses of Roma-street Railway Station
 Base of the Treasury Building

¹⁸ Proc. Roy. Soc. Qld., xxx, pp. 137-140

Abutments of Victoria Bridge
St Mary's Church, Kangaroo Point
Parts of the University
Gregory-terrace School
Numerous Retaining Walls
The Holy Name Cathedral

REPORTS ON QUARRIES

Bowser and Lever's Quarry

This is the largest of the quarries and is situated opposite Rosemount Hospital at O'Connelltown. A cliff about 60 ft high is being worked and the base of the tuff has not yet been reached. It is from this quarry that most of the material of recent years for building stones has come. Here the tuff varies from pale pink to dark purple in colour, and all the material with the exception of a small quantity of the dark and pale green varieties is good. The dark-green material does not weather as badly as the pale-green and may be used as a road metal.

The best of the material is used for building stones, kerbstones, and water plates, and then by means of a grader the rest after crushing is sorted and used for road metal, footpath dressings, and tennis-court dressings.

Windsor Quarry

This is much smaller than Bowser and Lever's quarry, and the material owing to weathering is not so good. It is situated in a loop which occurs in the outcrop of the tuff near the old Windsor Shire Council office. Jointing is very irregular. Work has now ceased in this quarry.

Exhibition Quarry

This is not being worked at the present time, but a good deal of rock has been previously obtained here, where a cliff about 40 ft high is to be seen.

Leichhardt Street

This quarry, although not being worked now, has been the source of supply of a quantity of stone which has been used in the buildings of Brisbane as road metal and for other purposes. It was one of the earliest to be opened. The material here shows great variety in quality, and at the base the hard silicified band so well seen at the junction of Ann and Gotha streets also occurs.

Kangaroo Point

At Kangaroo Point a cliff about 100 ft high is to be seen. The great disadvantage of the rock here is the presence of elongated inclusions of a whitish material which decomposes very rapidly. It is now used only as occasion demands for road metalling, etc.

Brisbane Wharves Ltd

The rock here is rather fine-grained, compact, and free from inclusions. It is nearly white in colour and it has the disadvantage characteristic of all the white varieties in that it grows moss easily. The material is mostly used for road metalling.

Morningside

This is only a small quarry, and was formerly partly owned by the Bulimba Town Council and partly by that of Coorparoo. That owned by Bulimba has the better material, which is fairly highly silicified and mostly pink in colour. The material owned by Coorparoo is in some parts very much altered. The size of the inclusions in the rock here are a distinct disadvantage, since it causes it to disintegrate more easily. The material is used for road-making, etc.

St Lucia

This material is white in colour, relatively free from iron staining, and is used locally as a road metal. The quarry is not large but a face about 20 ft high is at present being worked. These are the only points of outcrop which have been worked up to date on an extensive scale, but as occasion arises that which occurs in other areas will probably be used.

Happy Valley

A quarry has been opened on the Happy Valley road near Stafford, and quite recently several specimens of precious opal have been obtained there.

The mineral, which so far has not been found in any quantity, shows the beautiful play of colours seen in the more valuable opal. This is the only locality known to the author in which precious opal has been found in the tuff, although a few isolated specimens of common opal have been obtained from the Windsor quarry.

The tuff itself resembles that found in other parts of Brisbane, showing great variety in colour, hardness, etc., although the specimens containing the opal were all of a deep-purple tint.

At the base of the quarry the rock shows a distinct tendency towards bedding.

ACKNOWLEDGMENT

In conclusion, the author wishes to thank Dr Bryan, of University of Queensland, for his generous and invaluable assistance in revising this work, Professor Richards for assistance and encouragement, Mr Patten for making the chemical analysis, Mr A N Falk for preparing the micro-photographs, and her fellow students who accompanied her on the more far distant field excursions.

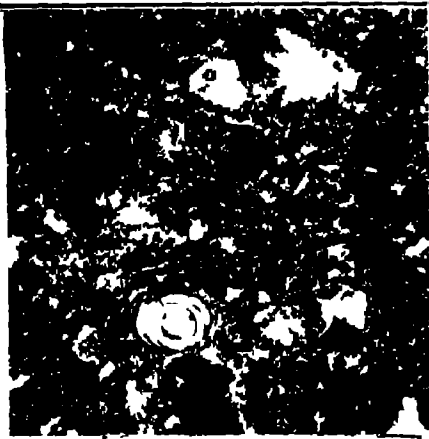
PLATE VIII

Microphotographs of specimens of the Brisbane Tuff taken in ordinary transmitted light

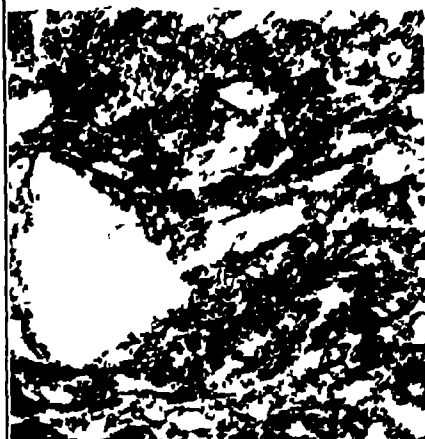
- 1 Typical tuff from Morningside $\times 14$
- 2 Typical tuff from Collin's Wharf $\times 14$
- 3 Typical tuff from Morningside $\times 30$
- 4 Typical tuff from Morningside $\times 30$
- 5 Hard band at base of tuff, Gotha street, $\times 30$
- 6 Hard band at base of tuff, Collin's Wharf, $\times 30$



1



2



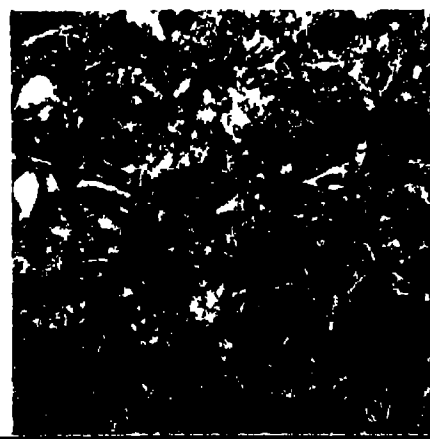
3



4



5



6



Photograph of cutting in Ann street Brisbane to show the relationship of the Brisbane Tuff to the Brisbane Schists. The white line has been drawn to mark the position of the base of the Brisbane Tuff. Between this and the Brisbane Schists there are a few feet of freshwater shales. The section has now disappeared having been removed in the preparation of the foundations of the Catlin Hotel on the Holy Name. The partly constructed wall is built of blocks of Brisbane Tuff carried almost *in situ*.

The Major Factors in the Present Distribution of the Genus *Eucalyptus*.

By D A HERBERT, M.Sc., Department of Biology, University of Queensland

(Read before the Royal Society of Queensland, 26th November, 1928)

The genus *Eucalyptus* to-day ranges from Tasmania in the south to Mindanao in the north. By far the greatest number is found in Australia and its continental islands, four Australian species extending beyond the continent to eastern Malaysia, two others being endemic there. The island of Flores represents the westernmost outpost of the genus in the Malaysian Islands, and the New Britain Archipelago the easternmost. Great gaps indicate a former wider distribution in Malaysia. To-day most of the species of the genus are concentrated in the extra-tropical part of the continent, especially in the south-eastern and south-western corners.

Thanks to the monumental work of the late J. H. Maiden, our knowledge of the range of the species, though still far from complete, especially in the localities remote from the centres of settlement, is sufficiently advanced for a detailed examination of their distribution and for a revision of the earlier theories as to the origin and development of the genus. Such is the object of this paper. The nomenclature adopted is that accepted by J. H. Maiden in his *Critical Revision of the Genus Eucalyptus* (1). Though his judgment is by no means universally accepted in many cases, his work represents a single view-point of the genus as a whole, and an unreserved acceptance of his naming for all species avoids the lack of balance which would be unavoidable were other opinions taken into account. Baker and Smith, for example, are less conservative in their definition of species than Maiden and their census of plants of their State (New South Wales) would include a large number of names which are regarded as synonyms in the *Critical Revision*. In Western Australia, Maiden's conception of the genus is usually accepted, and most of the more recently described species from that State have been named by him. It would therefore give New South Wales an inflated census as compared with Western Australia were the justice of Baker and Smith's contentions to be considered. As this paper is largely comparative, the tendency of a single authority to conservatism or errors in the delimitation of species, if such a tendency is claimed, is largely cancelled.

SURVEY OF LITERATURE

The question of the origin of the Australian flora was first considered systematically by J. D. Hooker (2) in his introductory essay to the *Tasmanian Flora*, published in 1860. He pointed out that the dominant families of Australia were for the most part dominant in other parts of the world. Of the nine largest families in Australia six are the

largest in the world, while the peculiarly Australian families are few. He recognised in addition to the autochthonous element the presence of Indian, Malayan, and Polynesian types in the north, New Zealand and South American types in the south-east, and an African element in the south-west. An assemblage of New Zealand, Fuegian, Andean, and European genera on the mountain tops was regarded by him as possibly the result of immigration, though in some cases the possibility of the alteration of Australian types was not lost sight of.

A considerable literature has grown up round the subject of the origin of the genus *Eucalyptus*, and the almost unanimous opinion of recent writers is that it originated in the warmer parts of the continent. Deane (3), for example, regarded the north and north-east as the original home of the capsular fruited *Myrtaceæ*, and that from these developed the fleshy fruited types of the family which spread to Asia and the other continents. The distribution of the *Myrtaceæ* is against such a hypothesis, as has been pointed out by Andrews, and capsular fruits are not necessarily always ancestral to baccate types. One point, however, is that Deane looks on the north as the starting point of the genus. Cambage (4, 5) considers that the early *Eucalypts* flourished in a warm climate, probably in Northern Australia. Andrews (6) is of the same opinion, reached by a consideration of the *Myrtaceæ* as a whole.

The earlier work where special attention was given to the history of *Eucalyptus* was that of Unger (7) and Ettingshausen (8). In 1865 Unger's work on "New Holland in Europe" appeared in the *Journal of Botany*. This was a translation of a lecture given by him in 1861, in which he presented the fossil evidence of the presence in the Eocene of Australian types in Europe. *Asiucarias*, *Eucalypts*, *Santalacææ*, and *Proteacææ* were described, and the conclusion reached that New Holland plants had travelled across a continental connection through Asia to Europe in the Eocene, and that at that time the European climate was similar to that of Australia at the present day. Unger's work did not long go unchallenged. Bentham in 1870, criticising the paper, pointed out that a modern systematist would not determine the order and genus of an unpublished species on the evidence of a leaf fragment. Ettingshausen (1883) viewed the tertiary Australian flora as a cosmopolitan one, comparing its fossil *Eucalypts* with those described from Europe, the Arctic Zone, and America. The dissociation of mixed floras such as those of the Eocene into elements now found in different climatic zones has more recently been stressed by Guppy in his *Theory of Differentiation*. Palms and poplars then found together are now separated. Ettingshausen's conception of the Australian Eocene flora was that of mixed types, the *Eucalypts* having since died out elsewhere. His deductions are based on fossil evidence, the soundness of much of which has been repeatedly questioned. Deane in 1896 attacked his conclusions as to a cosmopolitan tertiary flora, pointing out that there was nothing to prove that Australian groups existed outside Australia in tertiary times. Specimens referred to the genus *Eucalyptus* in North

America are now regarded by Berry (9) as being closer to *Myrcia* and *Eugenia*. This authority suggests that the Eucalyptus-like remains in North America be referred to the genus *Myrcia*, or alternatively to Heer's genus *Myrtophyllum*, which contains those Myrtaceæ represented by leaves whose generic relations cannot be determined with certainty. Amongst the European forms described as Eucalyptus are *E. oceanica* Unger and *E. Geinitzi* Heer, the former is similar to *Myrcia vera* Berry from the North American Eocene, and the latter is amongst those types referred to *Myrcia* or *Myrtophyllum*.

From the point of view of origin of the genus Eucalyptus the fossil evidence seems to point to a local development rather than to a former cosmopolitan distribution. The fossil Eucalypts described from Europe and America are from leaf material only, except in a few cases, and Maiden never saw a fruit referred to the Cretaceous or Tertiary that he agreed in referring to the genus.

Undoubted Eucalyptus remains from Australia have been described from Tasmania, Victoria, New South Wales, Queensland, and South Australia by McCoy, R. M. Johnson, Ettingshausen, Deane, Chapman, Patton, and others. Sub-fossil remains assigned to *E. obliqua*, to the *amygdalina* type, *E. cf. melliodora*, and *E. aff. piperita*, have been reported and are listed by Chapman (10).

Eucalypts with transverse leaf venation extended to Tasmania in the Eocene, *E. Kayseri* and *E. milligani* being of this type. Deane (11) points out that this is about 4° farther south than the present southern limit of the transverse type, and is to be expected considering the difference of climate in the Eocene and Miocene. Chapman records leaves of the *amygdalina* type probably Miocene, from Redruth (Victoria). Ettingshausen's fossil plants from Oxley and Darra were assigned by him to the Cretaceous, but are now regarded as Tertiary, Jones (12) tentatively places the Redbank Plains series, in which they were found, as Eocene or Oligocene. Amongst the plants described are Eucalypts of the transverse and oblique types of venation. Fragmentary though it may be, the fossil evidence indicates that the earliest leaf types discovered were differentiated into transverse and oblique types, and that the extreme obliquity of vein angle of the *amygdalina* type was also developed back in the Tertiary.

Baker and Smith (13) in 1902 formulated a diagram showing their conception of the evolution of the Eucalypts as evidenced by their botanical and chemical characters. Their work was founded mainly on the chemical constituents of the oils of the species examined. "Assuming Angophora to be the older genus," they pictured Eucalyptus as developing through *E. tessellaris* and *E. trachyphloea*, and a genealogical tree with numerous side branches was constructed from the living species. Species of undoubted affinity, such as *E. maculata* and *E. citriodora*, were widely separated in their scheme. In the second edition of their work (1920) they present a diagram of the same type, but with more species included and with definite places for some species

previously placed only provisionally. Some alterations have been made in the placing of a few species. Here for example, *E. citriodora* is shown as a descendant of *E. maculata*. *E. rostrata* is shown as a descendant of *E. leiocornis*, and many of the lines consist of chains of related species. *E. rostrata* var. *borealis* is, however, given quite a different line of descent from *E. rostrata*. This variety was established by Baker and Smith on chemical characters only, morphologically it is indistinguishable from the typical *rostrata*. To give such a variety a different line of descent is in itself a condemnation either of the genealogical table which would separate a variety from its parent in such a way, or of the value of chemical constitution as a taxonomic character. The Western Australian endemic species, *E. gomphocephala*, which is restricted to the coastal limestone, is shown with a series of immediate ancestors which are restricted to the south-eastern portion of the continent. The series is *Ridsoni*, *Gunnu*, *Luehmanni*, *tæniola*, *gomphocephala*. *E. Ridsoni* and *E. tæniola* are Tasmanian endemics, *E. Gunnu* is Tasmanian and S. E. Australian, and *E. Luehmanni* is a New South Wales species. *E. elaeophora* of S. E. Australia is shown descended from the pan-Australian *E. rostrata* through the Western Australian endemics *marginata*, *occidentalis*, and *salubris*. The geographical range of these and other examples that might be taken is, to say the least of it, not in harmony with such a genealogy, and, when considered in conjunction with the lack of morphological affinity between many of the species, shows the misleading and inaccurate nature of such a table.

Andrews suggests that the presence of phellandrene and certain other constituents in the oils of some species is of importance, at least in part, in resistance to cold, because the *Metrosideraceæ* and *Myrtaceæ* are not as resistant as the *Eucalypts* containing these oils. This he regards as an important acquisition from the point of view of the development of the genus. Cuthbert Hall (14) in his work on the evolution of the *Eucalypts* in relation to the cotyledons and seedlings, carried the idea further. "*E. macrohyncha* and *E. capitillata* by the development of a pinene eucalyptol-phellandrene oil have been enabled to spread over the south-eastern States and to work on to the mountains, while *E. obliqua*, by the development of a piperitone oil, has been able to establish itself over the mountains from the Queensland border to southern Tasmania." Again, "Chemically they (the *corymbosa* group) do not seem to have made much progress and have failed to develop eucalyptol, phellandrene, piperitone, aromadendrol, and so have been unable to leave a sandstone formation or to penetrate to the high alpine regions or dry interior."

Such assumptions as these are too great a load for the evidence to bear. The function of the essential oils in the metabolism of the plant is very uncertain. Doubtless they often have a protective effect against potential enemies, but their physiological function, if any, is unknown.

The history of the genus according to Cambage, as expressed in his various important papers on the subject, is briefly as follows —

Originating in the warmer parts of Australia the early Eucalypts were of the bloodwood type. Their leaves were opposite and horizontal, and had transverse venation, the anthers opened in parallel slits, and the fruits were generally larger than those of the present day, the main constituent of the oil was pinene. From this early type new types evolved by the development of petioles, oblique venation of the leaves, and various bark textures. Amongst these the *Boxes*, whose anthers open in terminal pores, have cineol as an important oil constituent. In cooler regions the *Renantheræ*, with kidney-shaped anthers, developed, here pinene is a very minor oil constituent, if present at all, the leaves have an almost parallel venation or with the few lateral veins showing an angle of less than 25° with the midrib. The *Peppermints* are included in this group, in which the greater vein-angle of the juvenile foliage indicates that the ancestral forms had a more transverse venation. The Miocene climate was mild and warm and Eastern Australia fairly level. The uplift which resulted in the formation of the Main Divide at the close of the Tertiary (the Kowanko period) had a pronounced effect on the distribution of Eucalypts. Three distinct climatic zones were created—the moist eastern face of the mountains, the drier western slopes, and the cooler mountain regions. None of the Eucalypts of the interior occur in Tasmania. The renantherous types have migrated northwards along the mountains into southern Queensland, perhaps assisted by the Pleistocene glaciation period.

Dr Cuthbert Hall's work on the cotyledons and seedlings shows that their morphology is a valuable taxonomic character. The cotyledons of the various species of *Angophora*, except *A. cordifolia*, are reniform like those of the Bloodwoods, and indistinguishable from them. The primary leaves of the latter, however, become petiolate and later alternate and often peltate. He classes the cotyledons into two groups, entire and emarginate, the reniform bloodwood type and the Y-shaped type, illustrated by *E. cornuta* and other species (both eastern and western), being at either end of the series. The shape of the cotyledon is useful in determining the affinities of many species, and the evolution of cotyledonary types has progressed along definite lines. Hall attempts to correlate this with adaptation to "Australian conditions" (p. 525). He pictures the necessity for the reduction of the large bloodwood cotyledon shown in *E. trachyphloea*, the evolution of the deeply bifid cotyledon in Western Australia and as far north as Western Queensland. Reduction of cotyledons, however, is not confined to dry areas, and these organs are ephemeral, representing a stage of the plant's life history usually passed under favourable moisture conditions. The various types contain widely differing species of Eucalypts, and in a number of cases natural groups (based on other characters) have

members with different types of cotyledons. It seems that various types have been produced independently in various parts of Australia, and that this character, like most of the others which are valuable in Eucalyptus taxonomy, has its limits and cannot be applied as a test of the past behaviour of the genus, evolutionary or geographical, except with extreme caution.

FACTORS GOVERNING THE DISTRIBUTION OF THE GENUS

Dr J. C. Willis (15), in a series of papers and in his book, has propounded the Age and Area Theory, which may be expressed in the following terms —

The area occupied (determined by the most outlying stations) at any given time in any given country by any group of allied species at least ten in number, depends chiefly, so long as conditions remain reasonably constant, upon the ages of the species of that group in that country, but may be enormously modified by such factors as the following — Chance (the operation of factors not yet understood), the action of man in opening up a country, cutting of forest, exploring, making fires, etc., interposition of barriers such as mountains, arms of the sea, broad rivers, deserts, sudden changes of climate from one district to another, and the like, geological changes, especially if involving changes of climate, serious changes of climate, natural selection, local adaptation, dying out of occasional old species, arrival of a species at its climatic limit, density of vegetation upon the ground at the time of arrival of a species, presence or absence of mountain chains in the land over which the species has to travel in arriving, relative width of union between country of departure and that of arrival (the wider it is the more rapid may be the spread of the species in the new country).

This definition is compiled from two of Willis's papers. In floral invasions he predicts that if a species enter a country and give rise casually to new (endemic) species, then if the country be divided into equal zones it will generally occur that the endemic species occupy the zones in numbers increasing from the outer margins to some point near the centre at which the parent entered. He has applied his hypothesis to New Zealand, and found that there were three maxima, corresponding, in his opinion, to three points of invasion—a northern, a central, and a southern. Willis's theory has many critics, and much of their criticism is answered by him in his various papers in the "Annals of Botany."

One of the points of importance that emerges from the mass of literature that has sprung up on the subject of age and area is the importance of relic species of endemics. We are chiefly indebted to Sinnott (16) for the attention that has been given to this matter. His objections were shown to be well founded in the case of the North American flora, which was the one with which he was most familiar. There, owing to the past changes of climate, the numbers of relic species

are relatively great, and their importance cannot be overlooked Guppy (17), one of Willis's chief supporters in the theory, investigated the flora of the Canary Islands, a region with a number of undoubted Tertiary relics, and found that this type of endemic had on an average a wider distribution than the more recent Mediterranean type Thus from this quarter the age and area hypothesis received further support

The genus *Eucalyptus* contains over 250 species, a sufficient number for an attempted application of the age and area hypothesis as a test for their point of origin It is first necessary to study the various factors modifying its operation Man's effect has been negligible A species like *E. mundijongensis* might be wiped out easily, but there is no evidence of the recent extinction of species of *Eucalyptus* by man, though the periodic firing of the forests by the natives restricted local distribution in Gippsland

THE EUCALYPTUS PROVINCES DEFINED

For a comparison of the Eucalypt population of the various parts of Australia it is necessary to divide the continent into provinces Tasmania by reason of its isolation is a natural province, but the delimitation of boundaries on the mainland is difficult The political boundaries are of no use, because they are artificial and the States are of widely different sizes As a guide a large map of Australia was prepared and the range of each species represented in outline Some are of such restricted range that they had to be represented by dots The completed map was covered with a tangle of irregular oval and triangular areas and liberally sprinkled with dots One thing, however, was plain There were a number of areas scattered round the margin of the continent in which the concentration of species was very marked The most prominent of these were eastern Victoria and southern New South Wales, the area between Sydney and Newcastle, the area between the Northern Rivers of New South Wales and Brisbane, the Rockhampton area (to a less marked extent), the Cairns district, the Northern Territory, the Kimberleys, the extreme south-west of Western Australia, the country east of Albany and north-west from there through the wheat belt, the Western Australian goldfields, and finally south-eastern South Australia and western Victoria Tasmania had previously been cut off because of its natural isolation Measurement showed that these centres of present distribution could be circumscribed for the most part by areas about 500 miles long and 200 miles wide The heart of Australia, poor in species, could not be divided up into small centres, but western New South Wales and Queensland had a number of dry-country species and could be marked off fairly definitely into a strip about 200 miles wide Going round Australia the coast was marked off into the regions indicated by the concentration centres in sections each approximately 500 miles

long In Western Australia the Kimberleys marked one natural region. West of Roebuck Bay is a long stretch of country poor in Eucalypts right round to Sharks Bay. This was divided into two regions, however, for the sake of uniformity and also because below the north west cape the rain falls mainly in winter. In south-western Australia one area was marked off from the Irwin River to a point a little east of Albany, another from Sharks Bay to Esperance, and the remainder the goldfields division, took in the concentration centre round Coolgardie. Though this latter area is somewhat larger than usual its endemic Eucalypts are mainly concentrated around Coolgardie and a much smaller area would give almost the same census. From Eucla to Port Lincoln the arid Bight country was marked off, and because many of the species here pushed into arid western New South Wales the area was continued east, cutting off the south eastern part of South Australia, which, with western Victoria, constituted another province. A strip of western New South Wales contained a small but characteristic collection of Eucalypts. The great arid area left after the separation of these strips was not divided up, for it contained only seventeen species altogether.

Though Australia is conveniently divided into a number of fairly definite regions in this way there is a good deal of overlapping. A tongue of southern vegetation, for example, extends into Southern Queensland along the New England Range, in Western Australia, goldfields forms are found occupying the wheat belt in local patches, and at Rockhampton western Eucalypts cross the divide and reach the coast.

Those species occupying more than one of these regions are regarded as wides, those occupying one only as endemics, the word 'endemic' here being used to indicate endemism with regard to the province only.

ISOLATION

The effect of isolation on endemism is well shown in the case of Tasmania. Of its twenty four species and varieties, thirteen are restricted to the island. The others occur also on the mainland, and of these five are in Victoria and adjacent parts of New South Wales only. The endemic species are all related to mainland species, eleven of them belonging to the *amygdalina* group. Newly developed species arising in Tasmania have been unable to spread to the mainland, being cut off by Bass Strait. The enforced restriction of locality means that a number of species which, given a chance to extend their territory, might have become wides, must remain endemic. Comparing its Eucalypt population with that of eastern Victoria and southern New South Wales we find that, though conditions are similar ecologically, the relative numbers of species of restricted range are much smaller. Taking the eighty-two species and varieties of the genus from the south-eastern corner, it is

found that fifty-eight are wides (all of them extending farther north, and a few pushing west to South Australia), the remainder being endemic. Reduced to a common basis, Tasmania has 50 per cent endemic species, the adjacent south-eastern corner of Australia as far north as, say, Kiama, 31.7.

South-western Australia is not as effectively isolated by the arid country as Tasmania is by the sea. It has six species in common with eastern Australia, and one with the northern part of the continent. These are dry-country forms which stretch across the intervening space. Against these there are 116 members of the genus which do not extend beyond the extra-tropical part of the State. As far as Eucalypts are concerned therefore, temperate Western Australia is very isolated. In the extreme south-west where the rainfall in places exceeds 40 inches per annum the country is heavily timbered. Inland the annual rainfall falls off rapidly, and three very distinct zones may be marked off—the well-watered south-western corner, approximately delimited by a line drawn from the Irwin River to a little east of Albany, a drier belt (including the wheat belt) from approximately Sharks Bay to Esperance, and the still drier goldfields area. On the east the goldfields area merges into the arid country of Central Australia and the Nullarbor Plain where the species of Eucalypts are few.

Corresponding to the differences in the rainfalls of these regions we have marked difference in the Eucalypt flora. The belts are rather isolated from one another by reason of their rainfalls, and the species endemic to them are characteristic. In the extreme south-west a few examples are *E. marginata*, *diversicolor*, *Jacksoni*, *Gudfoylei*, *fulva*, and *Toddlana*. In the drier belt *E. Forrestiana*, *Dongaiensis*, *Kondininensis*, and *casia* are amongst the endemics, though some of the most characteristic species, such as the York Gum (*E. fasciata* var. *torophleba*) are wides, overlapping a little into other belts. In the goldfields belt species of restricted range include *E. crucis*, *torquata*, *Jutsoni*, *corrugata*, *Le Souefii*, and *diptera*. The endemism in each of these areas is remarkably high, and is even more marked than that of Tasmania. In the south-western corner (Irwin River to Albany) there are twenty-five species endemic in a total of forty-two, this is equivalent to 59.7 per cent. In the drier belt inland from this and reaching to a line drawn from Sharks Bay to Esperance there are seventy members of the genus, and thirty-nine of them (or 55.5 per cent) are restricted. In the goldfields area thirty-four out of fifty-three (or 66 per cent) are not found beyond the region. The high percentages in this part of Australia point to long isolation. The actual number of species in the western part of extra-tropical Australia is smaller than that of the eastern half. Many of the newer species of Western Australia have been unable to extend their territory because of climatic barriers, whereas in the east, where the possibilities of spreading are much greater

owing to the more or less uniform rainfall along the coast the number of wides is proportionally greater. In the east too the mountains run north and south and species are enabled to push farther north on the highlands than they could on the lowlands. In the three mentioned areas of Western Australia there are ninety eight endemics and thirty four wides—that is 74.2 per cent endemism. Three extra tropical areas in eastern Australia (from Victoria northwards to Maryborough) have seventy seven endemics and eighty one wides this is equivalent to 48.7 per cent endemism for the whole area.

These figures may be summarised as follows —

TABLE 1 COMPARATIVE ENDEMISM IN TASMANIA SOUTH WESTERN AUSTRALIA (IRWIN RIVER TO ALBANY) AND IN VICTORIA AND SOUTHERN NEW SOUTH WALES

	Endemics	Wides	Total	Per Cent Endemism
Tasmania	13	13	26	50.0
South western Australia	25	17	42	59.7
Victoria and Southern New South Wales	27	28	55	51.7

TABLE 2—COMPARATIVE ENDEMISM IN EXTRA TROPICAL EASTERN AUSTRALIA AND EXTRA TROPICAL WESTERN AUSTRALIA

	Endemics	Wides	Total	Per Cent Endemism
Extra tropical Eastern Australia (Victoria to Maryborough) (three areas)	77	81	158	49.7
Extra tropical Western Australia (Shark Bay to Fremantle) (three areas)	98	104	202	74

These figures speak for themselves as regards the effect of isolation on endemism. The major isolated zones are those of Tasmania and temperate Western Australia and the contrast is shown against zones where expansion is possible. There are in addition numerous small isolated regions such as the coastal dune limestone of Western Australia or the highlands in North Queensland. In the former we have a characteristic endemic species in the tuart (*E. gomphocephala*) which does not occupy the neighbouring granite country. In the region between Bowen and Princess Charlotte Bay there is an increase in the percentage of restricted species as compared with areas of similar size elsewhere in Northern Australia. Here we have nine endemics in a total of thirty (30 per cent). The contrast with adjacent regions is

not so marked as that between the Western Australian regions and some of those of the east, but it is striking. It may be shown in tabular form —

Area	Endemics	Wides	Total	Per Cent Endemism.
Maryborough to Bowen	3	26	29	10.3
Bowen to Princess Charlotte Bay	9	21	30	30.0
Gulf Country to North Australian Border	3	19	22	13.6
North Australia (N.T.)	5	21	26	19.2
Kimberleys	7	22	29	24.1

It will be noticed that the percentage has risen again when we come to the Kimberleys in northern Western Australia. Here again we have mountainous country, though not of so pronounced a character as that behind Cairns. The number of species is so low that one or two extra make a great deal of difference. If two of the mountain species, such as *confluens* and *argillacea*, were undiscovered, the percentage endemism would be comparative with that of the Northern Territory.

Such outlying regions with different climatic conditions from the surrounding country would naturally be expected to develop a somewhat different, though related, flora, and the sharp contrast in climate would tend to check the expansion of new species, thus producing a higher proportion of endemics.

On mountain tops are a few species of very limited range. *E. alpina* is in the highest parts of the Grampians, *E. parviflora* at Nimitybelle (3,500 feet), *E. de Beuzevillei* on summits in the Kosciusko district, *E. Mitchellii* on Mount Buffalo, *E. Moorei* on the highest parts of the Blue Mountains from Wentworth to Mount Wilson, and *E. Mooreana* on summits in the Kimberleys. *E. virgata* has given rise to *E. virgata* var. *jacinoides* in the Monaro, and to *E. virgata* var. *triflora* in the Pigeon House Mountain (N.S.W.).

TEMPERATURE

From the point of view of vegetation the tropical portion of eastern Australia may be said to be that portion of the country from about Maryborough north. South of this the winter frosts gradually eliminate the northern forms, though some extend as far south as Victoria. Such a boundary applies also to the Eucalypts. Coastal eastern Australia lends itself readily to migration within temperature limits, there being a long strip of land along the coast from Victoria to North Queensland with no pronounced physiographical barriers. The mountains run north and south. From the Northern Rivers of New South Wales northward the rainfall mostly occurs in the summer, south of that it is mostly in winter, but the transition is gradual.

A comparison of the various parts of the coastal belt, leaving out Tasmania on account of the effect of isolation on its flora, may be made by considering the total number of species and the number of endemics in the following coastal regions — (a) Eastern Victoria and southern New South Wales, (b) New South Wales as far north as Raleigh, (c) Northern Rivers of New South Wales and South Queensland as far north as Maryborough, (d) Central Queensland (Maryborough to Mackay), (e) North Queensland (Mackay to Princess Charlotte Bay)

TABLE 3—COMPARATIVE ENDEMISM IN TEMPERATE AND TROPICAL EASTERN AUSTRALIA

Area	Endemics	Total	Per Cent Endemism
Eastern Victoria and Southern New South Wales	27	85	31.7
Coastal Central New South Wales	36	111	32.4
Northern Rivers and South Queensland	14	71	19.7
Central Queensland	3	20	10.3
North Queensland	9	30	30.0

The greater number of Eucalypts in this coastal belt is located in the temperate zone. The high percentage of endemism of North Queensland is associated with the presence of the highlands and accompanying isolation. Three other regions of tropical Australia—the Gulf of Carpentaria country, Northern Territory, and the Kimberleys—may also be considered. The figures for these parts are as follow —

TABLE 4—ENDEMISM IN NORTHERN AUSTRALIA

Region	Endemics	Total	Per Cent Endemism
Gulf Country	3	22	13.6
North Australia	5	26	19.2
Kimberleys	7	29	24.1

It will be seen that for areas of about equal size the total number of species of Eucalypts is approximately equal, and that the number of endemics varies a little, especially in regions of rugged physiography. The numbers rise sharply as we go south, unless, of course, we push into the dry country (where, as is pointed out later, the genus is relatively unsuccessful in eastern Australia), and the endemism is also, on the whole, higher.

Taking the whole of tropical Australia and comparing it with the whole of the extra tropical portion of the continent we find that there are 30 species of narrow range and 39 of wide range in the tropics, while in the temperate portion there are 202 of narrow range and 93 wide. These figures include the two dry regions western New South Wales to western Queensland and Central Australia each of which lies on both sides of the equator. Fifteen of the western New South Wales and Queensland species are southern two northern and two common. In Central Australia eight are southern six northern and three common. Here in the dry country the greater development is in the cooler south, which is in keeping with the distribution in the better watered regions. The overlapping of species in temperate and tropical Australia is not great. *E. peltata*, *acmenoides*, *eugenioides*, *saligna*, *eudesmioides*, *tereticornis*, *pyrophora*, *cloeziana*, *exserta*, *rostrata*, *tessellaris*, *corymbosa*, *terminalis*, *bicolor*, *hemiphloia*, *microtheca*, *crebra*, and *melanophloia* are found in both. *E. Baileyana* though mainly temperate also overlaps a little. This overlapping takes place mostly in the east one dry country form *E. eudesmioides* being the only western Eucalypt found in both tropic and temperate zones. I am indebted to Mr C. T. Whit for some notes on the tropical range of some of these species.

The overlapping of species in the eastern part of Australia where the temperate zone grades off into the tropical may be used as a test for the direction of migration of the Eucalypts. In the area which takes in north western New South Wales and south eastern Queensland we have fifty eight species of wide distribution. Of these twenty are found in the tropics and fifty one in the more temperate parts of New South Wales and Victoria. Only six are found extending north and not south. Even if we exclude ten species such as *E. obliqua*, *E. regnans*, *E. altior* etc. which occur on the New England tableland and which are rather a special tongue from the south we still have forty one wide left which extend south—that is twice as many as extend north.

The wide in Central Queensland and Northern Queensland are fewer than in the southern part of the State. North of Maryborough to Bowen the total falls to twenty six. Seventeen have tropical distribution only sixteen extend into the temperate zone. North Queensland with its twenty one wide has eleven in the temperate zone. Seventeen of the total are in Central Queensland. Here in these two tropical provinces the great preponderance of southern forms which was so marked in the region embracing northern New South Wales and southern Queensland is missing. If, however, a map of Queensland is drawn with the distribution of its Eucalypts marked in it is seen that the areas do not centre in the north but that the wide extend to different distances many stopping just north of Rockhampton others pushing up a little further and a little further like a series of waves lapping on a beach. There is no definite northern centre for the eastern wide, nor is there any approach to one. Such a map indicates, if anything, an encroachment from the south. Wide of purely tropical distribution are for the most

part spread across Northern Australia fairly evenly, circumscribed by climatic barriers, and in mountainous regions showing an increase in the number of their associated (and derived) endemics

RAINFALL

A line drawn across Southern Australia from east to west from Perth to Newcastle passes through country of very diverse rainfall. Perth lies in an area having a rainfall of between 30 and 40 inches per annum. Then comes the wheat belt (20 to 30 inches), the goldfields (10 to 20), the dry interior (under 10), western New South Wales (10 to 20), and the eastern slopes and coastal plains of New South Wales (20 to 40, and in places even more). The numbers of Eucalypts and the proportions of endemics in these areas are as follow —

TABLE 5.—COMPARISON OF EUCALYPTUS POPULATION AND ENDEMICISM IN PROVINCES FROM PERTH TO NEWCASTLE

	Rainfall	Endemics	Total Species	Per Cent
	Inches			
South west Australia	30-40	25	42	59.7
Wheat Belt	20-30	39	70	55.5
Goldfields	10-20	34	53	64.0
Arid South Australia	Under 10	2	19	10.5
Western New South Wales	10-20	6	22	27.2
Coastal New South Wales	20-40 (or more)	36	75	32.4

The total number of species and the proportion of endemics fall off rapidly in New South Wales as we go west from the regions of higher rainfall, reaching a minimum in the arid interior of the continent. On the western side it rises sharply again, but there is not the same sharp gradation in numbers from dry to well-watered areas. The country within about 100 miles radius of Coolgardie is a spawning ground for dry-country species, and the greater proportion of the species endemic to this 10 to 20 inch rainfall are centred there. Nineteen of its species are wides and thirty-four are endemics. Five of the former are allies of *E. incrassata*, and so are nine of the endemics, that is to say, over one-quarter of the Eucalypts of the region belong to one advanced group. Ten of the remainder are allies of *Eucalyptus oleosa* (six wides and four endemics). The range of affinities in the species left over is not great. Nearly half of the forms found in the region are due to the multiplication of two groups. (In a more exaggerated way we see the Eucalypt flora of Tasmania composed largely of allies of *E. amygdalina*.) Were it not for these two successful groups we should have figures more comparable with those quoted for western New South Wales and western Queensland.

In the wheat belt of Western Australia ten of the seventy species are *incrassata* allies, six are wides and four restricted. They represent an invasion from the goldfields, and their exclusion makes practically no difference to the proportion of endemics in the area. The *incrassata*

group centres in the goldfields, and, though it extends eastward and westward, it has not had the same success as round the Coolgardie region, in the wheat belt its members are an overflow from the dry country

In the drier belts of Western Australia it is an outstanding fact that the Eucalypts are much more successful than they are in similar areas in the east, and no doubt the long continued stability of that portion of the continent has favoured a slow and steady development of eremean types

Eucalyptus is not such a successful type in the areas with a rainfall of less than 10 inches per annum. In the arid belt extending from the Western Australian border to western New South Wales there are nineteen species altogether, two only being endemic, they are mostly of the *incrassata* and *oleosa* type. In the country of similar rainfall from Sharks Bay north to the North-west Cape there are only three species recorded—*ostriata*, *dichromophloea*, and *murolthea*. Beyond this from North-west Cape to Roebuck Bay there are four wides and no endemics, though the rainfall is better and in places about 20 inches per annum is received

The great tract of arid country in the middle of the continent possesses only seventeen species of Eucalypts, five of which have a more or less restricted range. This great stretch of land is equal in extent to the whole of coastal eastern Australia, where about 200 species are found

EREMEAN TYPES

The arid stretch of country from the Great Australian Bight to North Australia is thus indicated as a very effective barrier against Eucalyptus migration. Stretching as it does from sea to sea, there is little chance of species avoiding it by skirting the coast from east to west as they do from north to south in Eastern Australia. There are a number of species which extend right across—for example *E. rostrata*, *dumosa*, *gracilis*, *transcontinentalis*, *oleosa*, *calycogona*, *incrassata*, *bicolor*, *leptophylla*, *pyramiformis*, etc., but with the exception of *E. rostrata* these are dry-country forms which do not connect the well-watered areas of east and west. There are two possible explanations of the eremean Eucalypts. They may represent an invasion of the arid region from either west or east, or they may be the present day representatives of the survivors from a flora adapted to moister conditions. The great development of eremean types in the Western Australian goldfields country, which has already been alluded to, would suggest the former hypothesis, and the long-continued stability of the western part of the continent would be favourable to its behaving as a reservoir of potential plant colonists. On either side of the arid country, however, we find a few species—*E. diversifolia*, *E. conglobata*, *E. angulosa*, *E. Flottumae*, and perhaps *E. Gillii*—with eastern and western distribution, but not found in the intermediate area. *E. Gillii*, however, is only doubtfully recorded from Coolgardie. *E. gracilis*, though extending across the continent from east to west, has a big break in its known distribution before it reappears at Normanton.

Eucalyptus rostrata, the Red Gum, which is spread over the greater part of the continent, is a special case. It is found in both east and west, in the dry country restricted to watercourses in moister regions ascending the hill-sides. It does not occur in Tasmania, but as it is also absent from south-west Australia and parts of South Australia, this is not necessarily due to its youth. It has allies on both sides of Australia—*E. tereticornis*, for example, in the east, and *E. rudis* in the west. *E. rudis* shows marked resemblance to the eastern *E. ovata*, and there are other vague indications of an earlier widespread and larger group of these allies. There is not sufficient evidence, however, to show whether *E. rostrata* has used the watercourses of the interior as migration lines, or whether these are its last refuges.

The distribution of the other species mentioned seems to indicate that the eremean *Eucalypts* are the descendants of survivors rather than of immigrants from neighbouring botanical provinces, and that, therefore, *E. oleosa* and *E. macarata* groups have lost ground. Much more definite evidence, however, is obtained by a study of the *Corymbosæ* and the *Eudesmiæ*.

CORYMBOSE

Thirty species and one variety of the important *Corymbosæ* or Bloodwood group are found in Australia, mostly in coastal localities. None are found in Tasmania or in New Guinea and the Malayan Islands. The present day species are mostly tropical. Counting one variety (*E. pyrophora* var. *polycarpa*) as a species, for it is distinct from its parent species and has a definite range and cannot be omitted from a comparison, we have twenty-two tropical species and thirteen temperate. Four of these—*E. corymbosa*, *E. terminalis*, *E. maculata*, and *E. trachyphloea*—are common to both zones. In other words, eighteen are restricted to the tropics, nine to the temperate zone, and four overlap.

No bloodwoods occur in Tasmania. The type with transverse leaves was formerly present, as is shown by the fossil record. At present the bloodwoods show a distinct preference for the warmer portions of the continent. *E. corymbosa*, which is found from north eastern Victoria to North Queensland, does not extend above 3,000 feet elevation in the mountains round Wentworth Falls (18), though the geological formation remains the same. Here we have an indication of the climatic limit of the species, and if we assume that an elevation of 900 feet is roughly equivalent to one degree latitude, it is seen that the southern limit of *E. corymbosa* is the climatic limit. It stops where it would be expected to. *E. eximia*, an endemic bloodwood of New South Wales extending from Jervis Bay to Hornsby, is recorded by Mr. Cambage as continuing to about 1,800 feet. It would appear, therefore, that at Jervis Bay it has reached its southern temperature limit.

In south-western Australia there are three members of the *Corymbosae*. The mild temperature of the region does not set any barriers of this nature, and *E calophylla*, the Marri or Red Gum, is widespread in the better watered parts to the south coast. The other species, *E ficifolia* and *E hamatrylon*, which occur almost in the extreme south-western corner of the State (*E ficifolia* is found to the west of Albany, and *E hamatrylon* between Jarrahwood and Busselton), are apparently young species. That *E ficifolia* at least has not reached its climatic limits is shown by the way in which it flourishes in other parts of the south-west of the State, when planted. The real climatic barrier to *E calophylla* is dryness. Its frontier is the edge of the wheat belt. No other bloodwoods are found in temperate Western Australia, the wheat belt and the drier areas beyond cut off the south-western bloodwoods from the rest of the group. They are the evidence of the retreat of this group from south-western Australia. To the north of the State their nearest relative is the widely spread *E dichromophloea*, which stretches from the Murchison in Western Australia round the north of the continent to Central Queensland, but which does not make contact with the territory of the marri. It is one of those bloodwoods which can tolerate a very dry climate, and, indeed, in north-western Australia is one of the very few Eucalypts which can hold their own. Its southern limit is about the same in east and west of the continent. The rainfall at the western limit is mainly in the winter, and at the eastern mainly in the summer, and, as there is a wide range in its amount, this is not the limiting factor. Topography, soil, and rainfall alone would allow of a further extension south, but where the temperate flora becomes dominant this Eucalypt disappears. It is evident that here too, as in the case of *E corymbosa*, we are dealing with a temperature limit to the range of the species.

In addition to *E dichromophloea*, *E ferruginea*, *E peltata*, *E Cliftoniana*, *E pyrophora*, and its variety *polycarpa*, which are also tropical, are forms which are the outposts of the group in arid and semi-arid localities. The other species are limited for the most part to the well-watered fringe of Australia.

E trachyphloea, found on Melville and Bathurst Islands, occurs again in Queensland around Rockhampton and on Percy Island (a little over 100 miles due north of Rockhampton) and in various localities south of Brisbane. The wide gap in North Queensland and the Northern Territory indicates a retrogression in the drier parts of tropical Australia. It is one of the yellow-barks, and its allies, *E eximia*, *E peltata*, and *E Watsoniana*, are eastern. There is no existing species from which the Melville Island and Bathurst Island tree may have sprung independently. If such a species did exist at one time, and the distribution may be explained as an example of polyphyletic evolution, the parent has died out, so that retrogression has taken place in any case.

The following is the present-day distribution of the *Corymbosæ* —

TABLE 6 —PRESENT DISTRIBUTION OF THE CORYMBOSE EUCALYPTS

Region	Endemics	Total
Victoria and Southern New South Wales	1	4
Coastal New South Wales—Kiama to Northern Rivers	1	4
Northern Rivers to Maryborough	2	7
Central Queensland	0	7
North Queensland	2	8
Gulf Country	0	5
Northern Territory	2	11
Kimberleys	3	12
Broome to North west Cape	0	1
North west Cape to Murchison	0	1
Arid Interior	2	3
South west Australia	3	3
Total Tropical	8	23
Total Temperate	8	13

The budding off of endemic species as indicated in the table follows no rule. The relative numbers of species of restricted range do not vary a great deal from area to area, the numbers being too small to show much contrast. The number of wides, however, varies markedly. The Kimberleys and the Northern Territory possess the greatest total of bloodwoods, and being surrounded by drier territory many are unable to extend their area. To the west the number of wides falls to one, to the south to one, and to the east to four. The Gulf country and the dry interior separate the eastern strip of Eucalypts from those of the north, and migration round the coast under present conditions, in either direction is quite unlikely. The only widespread species with this range are *E. terminalis*, *E. dichromophloea*, and *E. trachyphloea*. The last-named has already been discussed. The other two can grow in sub-arid conditions, *E. terminalis* growing in relatively dry parts of western New South Wales and Queensland, *E. dichromophloea* being one of the few successful species in north west Australia. The Gulf country has five species—*E. terminalis*, *E. dichromophloea*, *E. minata*, *E. peltata*, and *E. setosa*. The first two are widely spread in the tropics, but the others have a distribution through the Northern Territory and the Kimberleys, and are not found in the eastern strip at all. *E. minata* has a close relative, *E. phænicea*, endemic in the Northern Territory. *E. ptychocarpa*, through which they are linked to the rest of the *Corymbosæ*, is a Kimberley and Northern Territory species. This does not prove anything, but is a slight indication that the central point from which it has spread was not eastern. *E. setosa* is in contact with its allies, *E. Cliftoniana* (endemic in the Kimberleys) and *E. ferruginea* in the western part of its territory. In the east it is not in touch with the closely allied *E. Torelliana*, an endemic of the east coast of North Queensland, which grows in competition with the Malayan element either in rain forest or on its fringes. *E. peltata*, the remaining Gulf species, is a dry-country

form ranging south through the dry country to Chinchilla. It, too, is out of contact with *E. Torelliana*, its closest surviving relative.

E. Torelliana is thus seen to be isolated from its northern kin, but it is in contact with the lemon scented gum *E. citriodora*, which in turn is in contact with *E. maculata*. *E. citriodora* has not reached its climatic limits and is probably an offshoot of *E. maculata*, of which it was for a long time regarded as a variety. *E. Torelliana* comes nearest to *E. maculata*, though no longer in actual contact with it except through *E. citriodora*. Possibly here, too, we have a case of loss of territory by a widespread species, as it is difficult to believe that *E. Torelliana* has descended from *E. maculata*, through *E. citriodora*, which is so unique in the nature of its oil.

E. Aberqiana, the other coastal North Queensland endemic, has its nearest relative in *E. ptychocarpa*, a Kimberley and Northern Territory species, from which it is separated by several hundred miles of relatively dry country.

The Corymbosæ of the eastern coast, exclusive of Northern Queensland which has already been discussed, are *E. corymbosa*, *E. terminalis*, *E. dichromophloia*, *E. maculata*, *E. trachyphloia*, *E. intermedia*, *E. peltata*, *E. citriodora*, *E. Blossomei*, *E. eximia*, and *E. Watsoniana*. On their southern limit, as has been pointed out, temperature controls their range. *E. dichromophloia* and *E. trachyphloia* have been shown to have a distribution indicative of a dying out over wide areas. *E. eximia*, *E. peltata*, and *E. Watsoniana*, though closely related are separated from one another. The remaining species along the coast are in contact with their relatives and do not show discontinuous distribution. They behave as would be expected, the wider occupying practically continuous stretches of territory, and here and there surrounding smaller areas of endemics.

The whole distribution of the Corymbosæ therefore indicates a former greater extension of the group throughout Australia. Lower temperature on the one hand and drier conditions on the other have forced the group from areas formerly occupied. The fossil evidence points either to their presence or the presence of allied forms formerly in Tasmania. At present the southern limit is one that is determined by temperature. Elsewhere in Australia the increasing dryness has left the three temperate Western Australian bloodwoods isolated from those of the rest of the continent. In the north and east the range of *E. dichromophloia*, *E. trachyphloia*, *E. Aberqiana*, *E. peltata*, *E. Watsoniana*, and *E. eximia* suggests a fringe of relict on the margin of territory formerly peopled with bloodwoods. The larger numbers in the Kimberleys and the Northern Territory, and the fairly uniform distribution of species in the east and west except where the climate is unfavourable, the difference between eastern and northern on the one hand and western and southern on the other, would seem to indicate a former central concentration of the group. The occurrence of fossil bloodwood

types in Tasmania shows that a retreat has taken place towards the north, and that the centre, though probably warm, was not necessarily located in that part of Australia which is tropical at the present day.

EUDESMIÆ

The Eudemiæ, given generic rank by Robert Brown under the name of *Eudesia*, and peculiar especially in the possession of calyx teeth, are widely spread in the warmer and drier parts of Australia. There are ten species, extending from the vicinity of Grafton northwards to Rockhampton, through western Queensland and northern Australia, the northern part of Central Australia, and down into the goldfields and wheat belt of Western Australia. *E. Baileyana*, which is found from Grafton to Rockhampton, is a temperate species, its isolated tropical locality, Dingo, being on the Blackdown Tableland. Its neighbour, *E. similis*, is not known to occur with it at the present day, and at their nearest point of approach they are about 200 miles apart, *E. similis* being found at Alice Downs in Central Queensland, a locality which is about that distance from the Blackdown Tableland. *E. lirata* from Bold Bluff in the Kimberleys is a close relative of both *E. similis* and *E. Baileyana*, and it is even more widely separated from them than they are from each other. Such a distribution indicates a loss of territory formerly occupied by the Eudemiæ. In the west is *E. eudesmoides*, which occurs from the Mogumber River in Western Australia north and east to Tanami Goldfield and the Victoria River. It has given rise to *E. tetragona*, *E. erythrocorys*, *E. Ebbanoensis*, and *E. Merricka* in the wheat belt and goldfields of south-western Australia. *E. tetragona*, which is found east of Katanning in the Stirling Ranges, and at various localities round Hopetown and Ravensthorpe, does not make contact with the parent species or any of its near kin. It, too, furnishes a little further proof of the retrogression of the group.

In arid Northern Australia *E. eudesmoides* surrounds *E. odontocarpa*, and, applying the Age and Area hypothesis, this latter species is to be considered an offshoot from the widely spread one with which it is closely allied. Northwards, but isolated from these others, is *E. tetrodonta*, widely spread across Northern Australia from the Kimberleys to the Gulf, and, like *E. Baileyana*, occurring in regions of better rainfall, such as Melville Island. It surrounds the allied endemic *E. lirata* in the Kimberleys.

It appears, therefore, that the Eudemiæ, though widely spread in Northern and Western Australia, are not of uniform distribution. Gaps separate the species from one another in the east, in the south-west, and in the north. They agree in general in being comparatively unsuccessful in the areas of better rainfall, *E. Baileyana* and *E. tetrodonta* being rather more successful than the others. These two, however, are not dominants in their formations. An ancient group, the Eudemiæ have receded from much of their territory. The evidence, such as it is, of their origin seems to point to its being southern rather than extreme

northern. *E. eudesmuoides* and its probable offshoots, *odontocarpa*, *tetragona*, *erythrocorys*, *Ebbanoensis*, and *Merricks* are dry-country species mainly of temperate zone distribution, and those that are tropical do not push into the actual northern centres of Eucalypt population. *E. Baileyana* is temperate except for the outlying Blackdown Tableland locality, which climatically is not tropical. The three remaining species—*E. similis*, *E. tetradonta*, and *E. lirata*—are well within the tropics. If the wide *E. tetradonta* were the parent of *E. similis*, as it apparently was of *E. lirata*, it must formerly have had a distribution which it no longer possesses, unless it is *E. similis* which has contracted its boundaries.

The present distribution of the ten known species can best be accounted for by assuming that the group originally had a wide distribution in the milder parts of Central Australia when the region was better favoured as regards rainfall. With the increasing aridity it dwindled, the species at present fringing the original area occupied. Such a retreat has occurred with other plants such as the palms. Sir Baldwin Spencer (19) mentions the case of a small colony of palms in a gorge about two miles long in the Macdonnell Ranges, entirely isolated, but indicating a climate formerly very different from that of the present. The distribution of the Eudæmiæ is quite different from that of tropical groups, such as *E. alba* and its allies, which extend across the tropics continuously, the endemics occupying smaller areas in the territory covered by the wides.

EXTRA-AUSTRALIAN SPECIES

No Eucalypts are found on the numerous oceanic islands which fringe the northern coastline, though on the continental islands (Fraser, Palm, Dunk, Magnetic, etc.) they are common where conditions of soil and rainfall are suitable. On Bathurst Island (north-west of Darwin) there is an endemic species (*E. Hillii*) not yet recorded from the mainland, otherwise the species on the islands are those found on the adjacent parts of the mainland. Only where the probability of land connection is great do we find such an extension of the Eucalypts to the islands. Guppy (20) found Eucalyptus fruits on the Valparaiso beaches, and cites them as an example of futile buoyancy, none of the species of the genus has become established naturally in Chile. The seeds have no chitinous coats like those of *Acacia* and are not adapted to saltwater transport. Maiden knows of no cases of mature seeds completing such a voyage, and points out that they fall out of the capsule readily after it has ripened. The genus extends beyond Australia through the northern islands as far as Mindanao in the Philippines. The gaps are wide in some cases. Four northern species are found in Papua—*E. alba*, *E. papuana*, *E. clavigera*, and *E. tereticornis*. *Eucalyptus alba* occurs in Australia from Gladstone northwards and across the north to the Kimberleys. In North Queensland it occurs with *E. tessellaris*, *E. terminalis*, and *E. tereticornis*. In the Kimberleys, according to Gardner, it occurs with *E. Spenceriana* and *E. miniata*. This is mentioned to show that some of the species which are its associates in Australia are not found in Papua. It is known also from

Timor and Flores with certainty, but has parted from the rest of the species there *Eucalyptus papuana*, which was originally described from Papuan material, is found in Bathurst Island and in the Kimberleys. (The records of *E. tessellaris* for New Guinea, Northern Territory, and north-west Australia are doubtful, and the specimens are referable to *E. papuana*.) *E. clavigera* is found across northern Australia from Broome to the Gulf. In Papua it has been collected at Port Moresby and the Astrolabe Range. *E. tereticornis* is found from east Gippsland to Papua, in North Queensland it is mostly variety *latifolia*, and it is this variety that is found on the Northumberland Islands and in Papua.

In addition, there are two species, *E. Naudumana* and *E. Schlechteri*, which are non-Australian. The former occurs along watercourses and in rain-forest country in Papua, New Britain, New Ireland, and the Philippines, and probably in the Moluccas and Celebes. It is closely related to *E. Schlechteri* from north eastern Papua, an endemic species of narrow range. Other than this it has no close affinities, though there may be some distant connection with *E. Cloeziana*, which has a tropical and sub-tropical distribution in eastern Queensland.

These extra-Australian Eucalypts, though ranging in some cases far beyond this continent, are limited in so far as none of them cross Wallace's line (as revised by Merrill) on the west. Wallace's line as originally defined (21) ran between Bali and Lombok, between Borneo and Celebes, and south of the Philippine group. Merrill (22), from a consideration of the flora (especially the Dipterocarps) and the fauna, has modified the northern part so that the line now runs from between Celebes and Borneo northwards, cutting off Palawan from the rest of the Philippines. It thus corresponds with the margin of the Asiatic continental shelf. It is the western boundary of a zoogeographic and phytogeographic area intermediate in character between Malaysia and Papuasia. The eastern margin of this is known as Weber's line, which approximately coincides with the Australian continental shelf.

E. alba and *E. Naudumana* have crossed Weber's line and are established in the unstable area between the Asiatic and Australian land masses. Such a distribution is made possible by the intermittent land connections which have existed from time to time in this archipelagic region, and which have facilitated the migration of other genera. A stream of Australian emigrants is represented by such genera as *Andropogon*, *Cladium*, *Centrolepis*, *Paterosoma*, *Thysanotus*, *Drumys*, *Gnaphalium*, *Acacia* (*A. confusa*, a phyllodineous species), *Pleurogynium*, *Stackhousea*, *Halorrhagis*, *Pimelea*, etc. Merrill (23) considers that seven families and over five genera in the Philippines must be considered Australian types, and that their sparse distribution in Formosa, China, and south eastern Asia indicates a long-continued separation of Luzon from the Asiatic mainland. That these types should have pushed northward to the Philippines rather than westward to Borneo, Java, and Sumatra is accounted for by the past geological history of the Malayan region. Between the Asiatic and Australian continental shelves lies an

unstable archipelagic area with both flora and fauna intermediate between that of Western Malaysia and Papuasia. There is abundant evidence pointing towards the lack of direct land connections across this area linking east and west, though there have apparently been opportunities for migrations via the Philippines. Thus it happens that Australian plants find their way northward to the Philippines but may not be found in Java or Borneo. Merrill's work on the distribution of *Dipterocarpaceae*, supported by a consideration of other constituents of the flora and also of the fauna, indicates that the Borneo-Mindanao connection which admitted this group from Western Malaysia was more extensive than the connection of Mindanao with Celebes or Gilolo, which also permitted migration towards New Guinea. It was at this period that the Australian types were enabled to reach the Philippines, and amongst them we have *Eucalyptus*. Merrill's conclusions as to the migrations of *Dipterocarps* are lent support by Diels's work (24) on the Papuan species of the family. Schlechter, too, finds that the orchids of the Celebes belong to the Papuanian region. The whole of the flora of the intermediate area of islands is a transition, and the modified lines of Wallace and Weber mark its boundaries.

A numerical comparison of *Eucalypts* in (a) North Australia from the Kimberleys across northern Australia to the Gulf of Carpentaria, (b) Papua and the New Britain archipelago, and (c) the transitional Timor-Celebes-Philippines zone, is as follows—

TABLE 7.—COMPARISON OF EUCALYPTUS POPULATIONS AND ENDEMISM IN NORTHERN AUSTRALIA AND IN NON-AUSTRALIAN ISLANDS

	Endemics	Wides	Total
North Australia	16	30	46
Papua and New Britain Archipelago	1	5	6
Intermediate Zone between East and West Malaysia	-	2	2

These areas are of approximately equal size, but even if only the country round the Gulf of Carpentaria is taken as representative of tropical Australia we still have three endemics and nineteen wides—a total of twenty-two. There is a very marked concentration in North Australia. In Papua where *Eucalyptus* formations exist, ecological conditions are similar to those of northern Australia where the same species occur in company with other species not found beyond the Commonwealth borders. None of the bloodwoods, on which so much argument has been based by various authors of papers on the origin of the *Eucalypts*, occur beyond Australia. *Eucalyptus alba* and *E. tereticornis* are species of very wide temperature toleration, and *E. clavigera* is also widely spread in northern Australia. *E. papuana*, also widely spread on the mainland, is closely related to *E. tessellaris*, which extends

down into New South Wales. The far-flung distribution of these species in Australia indicates that, apart from having the power of spreading, they have also had time to do so, in other words, they are long-established species which, given the opportunity of pushing beyond Australia to the north, might be expected to do so. That endemic species related to them, or wider of more restricted range, have arisen in Australia and not in Papua, points to their Australian origin. *E. alba*, the species with the widest distribution (Australia to Papua, Timor, and Flores), has three Australian relatives of restricted range—*E. Houseana* in the Kimberleys and the Northern Territory, *E. populifolia* in the dry interior of New South Wales and Queensland, and *E. pallidifolia* in North Queensland and the Northern Territory. *Eucalyptus papuana* and *E. clavigera* belong to the Angophoroideæ with seven species—*E. papuana*, *E. clavigera*, *E. tessellaris*, *E. grandifolia*, *E. aspera*, *E. Spenceriana*, and *E. brachyandra* in Australia.

The other, with a mainland distribution, *E. tereticornis*, has Australian relatives of restricted distribution in *E. Bancroftii*, *E. amplifolia*, *E. exserta*, *E. Blakeleyi*, and in the south of the continent it grades off into *Eucalyptus rostrata*.

The non Australian species *E. Naudumana* and *E. Schlechteri* are a special case. *E. Naudumana* (*E. deglupta*) is a dominant species along rivers and in dense forests in Papua, New Britain, New Ireland, and parts of Mindanao. *E. Schlechteri* is an endemic Papuan species described in 1922 by Diels from north-eastern Papua. Closely allied to *E. Naudumana*, it is to be regarded as an offshoot from it. Taxonomically these two species are members of the Renantheræ, which reach their greatest development in temperate eastern Australia.

The other extra-Australian species are sclerophyllous forest types. *Eucalyptus* in the tropics usually fails under moist conditions, the Malayan element occupying the ground densely and excluding it. The dense rain forests are, as a rule, no place for the light-loving eucalypt, though in the more open monsoon forests in Northern Australia open forest types may occur. Columnar species, such as *E. saligna* and *E. Torelliana*, are more adapted to such habitats owing to their height and their rapid growth, and can compete to a certain extent with the tropical rain-forest types, though they mainly do so in the more open parts such as the forest margins and along streams.

In temperate Australia rain forests are often dominated by these columnar Eucalypts, as, for example, *E. regnans* and *E. gomocalyx* in Gippsland. *E. Naudumana* is of this type, and is better adapted for the struggle in moist megathermic regions where the Malayan types are usually so much more successful. Its scattered distribution over the region from the Bismarck Archipelago westwards to Wallace's line shows that it has lost much territory which it must have once occupied, though still locally successful and dominant. One of the most striking characteristics of the forest formation of the wet region from Cardwell (North Queensland) north along the coast is the dominance of Malayan types

over the Eucalypts, except in dry, sandy localities. Dense rain forest or monsoon forest occupies all but the driest parts of the area. On the forest floor where the light filters feebly through the dense canopy, only shade-loving species can survive. Brandis (25) has shown that in the case of *Shorea robusta*, and Brown (26) in the case of *Parashorea malaanonan*, that there is a pronounced suppression period in the early life of these types. Merrill considers that most Dipterocarps have this adaptation. In North Queensland rain and monsoon forests it is common to see numerous small plants belonging to the same species as the dominant tree types, while there are a few small trees of the same species. These small plants are apparently enduring a suppression period, and will ultimately die unless an opening occurs in the forest. During the 1926 cyclone in the Cairns district, such openings were torn in the forests, and within a few months the suppressed seedlings were shooting up rapidly.

In this district, where the conditions of temperature and rainfall are similar to those found throughout the greater part of the Malayan Islands, competition of this type suppresses the Eucalypts. Across the greater part of tropical Australia we have megathermic conditions combined with a fairly low rainfall, or even where the annual precipitation is fairly high, as at Darwin, its seasonal nature is very marked, and a long dry season prevents the appearance of rain forest. Here the Eucalypt becomes established. Twenty miles west of Cairns, where the rainfall suddenly diminishes as we come to the western slope of the divide, the rain forest disappears and Eucalypts take its place. Along the coastal plain of the dry belt south of Cardwell the same thing happens, though in the moist gullies the rain forest and monsoon forest reappears. In the temperate zone passing from dry country to the well-watered country of, say, Gippsland, we do not find the Eucalypts being suppressed in the same way. Tall, rapidly growing species such as *E. regnans*, *E. gomicalyr*, and *E. immanis* dominate the temperate rain forests. In the tropics, under similar conditions of rainfall and soil moisture, the Malayan types would have ousted the autochthonous element.

For the most part the islands from the New Britain Archipelago to the west and north-west combine the two factors of high uniform temperature and abundant rainfall which have in the Cairns district suppressed the Eucalypts. The four Australian species, *E. tereticornis*, *E. alba*, *E. papuana*, and *E. clavigera*, which are found in this area are not of the tall shaft-trunked type, and prefer regions with a rainfall of 20 to 40 inches per annum. *E. tereticornis* is certainly fond of river banks, and therefore of moist conditions, but it must have plenty of light, and cannot compete with rain-forest types. *E. Naudumiana* is of the same growth form as *E. regnans* and other species common in temperate rain forests, and, while able to form pure formations along rivers, is also adapted to life in the rain forests. In this it is rather exceptional amongst tropical Eucalypts, and it is not surprising in the circumstances to find it as far north as Mindanao.

GENERAL

Most of the conclusions reached by the study of the present distribution of the genus have been presented and discussed under the various sections of this paper. Some general remarks on the subject may now be made to summarise the conclusions from the evidence presented.

The fossil evidence shows that the Eucalypts with the transverse type of venation have receded from Tasmania. The temperature at the altitudinal limit of *E. corymbosa* on the mainland mountains is approximately that of the region where its southern outposts are found, so that it is temperature which is the present limiting factor in this case. During the last glacial period, when David (27) considers the snow-line to have come down fully 3,000 feet below the present level, the cold must have had a profound effect on the more southern bloodwoods. This difference in snow-line would indicate that the temperature conditions which now limit the progress of *E. corymbosa* southwards would have been somewhere about the latitude of Newcastle. *E. cinnia*, which extends from Jarvis Bay to Hornsby and has been shown above to have reached its southern climatic limit, must either have occupied a more northern area at that time and have contracted its boundaries, or else be an endemic developed after the return of the bloodwoods at the close of the glacial period. Its present northern boundary is below the limit at which it could have existed at that time. The same remarks apply to *E. nou-raensis*, a more southerly endemic of small range. The contraction of area from the edges, especially from the northern boundary, without any outlines to show a former northern extension, though possible, is not likely, and even more unlikely when the two endemic species show the same behaviour. A pre-glacial evacuation of the south, a post glacial reinvasion, followed in the fulness of time by the development of these endemics, seems to have been the post-glacial history of this part of the Bloodwood group.

In the warmer parts of Australia low temperatures cease to restrict species. Here water supply is the deciding factor. Except in the case of a few species, *E. pyrophora* for example, the arid regions are unfavourable to bloodwoods. The distribution of the group round the borders of the continent is the result of the dying out of the group in the central regions as it became more arid. The committee on Quaternary Climates, appointed by the Australasian Association for the Advancement of Science in its published report (28), summarises the knowledge on the subject. Some of this consists of deductions from present distribution of plants (based on the work of Cambage and of Andrews), and so cannot legitimately be used for explaining the distribution of the bloodwoods. Mammalian drift occurs in places and suggests a moist, if not wet, climate in the now arid interior, and a remarkable fauna of giant marsupials as the end of the Tertiary is pictured as being destroyed by the onset of arid conditions (29). The increasing aridity drove the bloodwoods to the edges of the continent, leaving the survivors to continue their existence within their temperature limits. That the group

is not a dying one is amply evidenced by the number of endemics that have been produced, some of which have certainly not yet reached the limits of their possible range. Additional evidence of retreat is shown by the distribution of the *Endemias* and even by the *eremian* forms. In the favoured areas of the continent, development of the genus subsequent to the dying out of the central flora has proceeded along different lines in east and west. Cambage's excellent account of the development of the genus in New South Wales deals with the colonisation of the mountains after the Kosciusko uplift and the development of the flora of the western slopes. In Western Australia conditions have been fairly uniform, the uplifts being comparatively small and the restriction of marine deposits being strong negative evidence in favour of an ancient land surface (30). Here, too, there is geological evidence of increased aridity, but even without this the isolation of the south western flora, and its definite relationships to the eastern, the survival of a few *eremian* *Eucalypts* of the same species in both east and west points to a former central *Eucalypt* population whose members gradually perished as they were subjected to increasing aridity.

The very wet regions in the tropics on the other hand are not favourable to the *Eucalypts*. The regions of heavy rainfall along the North Queensland coast, from between Cairdwell and Innisfail northwards, are remarkable for the failure of the genus. Practically the whole of the territory is occupied by rain-forest types, and the few *Eucalypts* are on the drier ridges, the sandy stretches, and in a few cases in the more open parts of the rain forest where light conditions are more favourable.

A number of facts concerning the present distribution of the *Eucalypts* must therefore be taken into account when discussing the origin of the genus *Eucalyptus*. They are as follow —

- (1) The *Eucalyptus* flora of cold regions is specialised
- (2) The *Eucalypts* have retreated from regions now arid but formerly well watered
- (3) Greater numbers occur in the temperate arid zones than in the tropical arid zones
- (4) *Eucalypts* have failed in competition with rain-forest types in the tropical parts of Australia
- (5) The species in moderately well-watered regions of the tropics are few in comparison with those in similar areas in the temperate zone
- (6) The species which have both a tropical and a temperate distribution in eastern Australia indicate a southern origin rather than a northern
- (7) The *Coymbosae*, often considered an unsuccessful type, though forced back with other types from the interior, have continued development in the coastal regions, though the Pleistocene glacial period destroyed them in the south. In southern New South Wales they are re-invaders, not a new type from the north

- (8) The geological and climatic history of Australia has been responsible for extensive dying of species of the genus, and the present barriers of climate and physiography (for example Bass Strait and the Great Divide) have so affected its spread that a simple application of the Age and Area hypothesis is impossible except in small areas and then only for a consideration of the local development of the genus

In brief it may be asserted that the drying up of Central Australia obliterated much of a well developed Eucalypt population leaving a marginal fringe of survivors. As the barriers of climate and physiography have changed considerably in the east involving a northward retreat and a southward re invasion in addition to the retreat from the central regions, it is not possible now to locate the point of origin of the genus. In view however of its present day requirements and of the reasons advanced, it seems certain that Eucalyptus first successfully established itself in that part of Australia which in late Cretaceous or early Tertiary times had a temperate climate and a fairly abundant rainfall.

SUMMARY

Most of the species of Eucalyptus are located inland and the coast in a belt about 200 miles wide. Isolation of Tasmania and south western Australia has resulted in a high proportion of endemism the term endemic being used to denote a species restricted to one only of the defined regions. This high endemism is not a proof of great age. Most of the eastern Eucalypts are temperate the total numbers and numbers of endemics decreasing north of Maryborough. Taking the whole of Australia we have 30 species of narrow and 37 of wide range in the tropics the figures for the temperate zone being 202 and 92 respectively. The number of species decreases rapidly as the arid regions are entered and the endemism is also less marked except on the Western Australian goldfields where the success of the *E. oleosa* and *E. incrassata* groups has raised the figures considerably. Ereman species such as *E. diversifolia* *E. Flotowii* etc. which are found in east and west but not in central Australia are regarded as relics. The bloodwoods are shown to be the descendants of a surviving fringe of forms which have retreated from the more central parts and the same is true of the *Eudamiera*. Evidence is presented to show that there has been a retreat of the bloodwoods from the south followed by a re invasion from the north. The extra Australian Eucalypts are emigrants and the genus is a comparative failure in Malaysia owing to climatic factors. Present day Eucalypts avoid the arid tropics the extremely moist tropics the arid temperate regions and the cold of the mountain tops. In the favourable parts of the tropics their numbers are very small as compared with those of similarly watered temperate areas. It is concluded that the genus Eucalyptus at the present day is a development of the fringe of species which remained round the coast after the destruction of the greater number of the species as the central part of the continent became more arid, and that the early Eucalypts established themselves in the well-watered temperate portions of the continent.

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The Royal Society of Queensland.

Report of Council for 1927.

To the Members of the Royal Society of Queensland

Your Council has pleasure in submitting its Report for the year 1927

Ten original papers were read and discussed before the Society during the year. Two public meetings of a popular character were held. Professor B. D. Steele, D.Sc., F.R.S., gave a lecture on "Oil in Queensland," and on the occasion of the Newton Tercentenary addresses were delivered by Professors T. Parnell, H. J. Priestley, and Mr. H. A. Longman. During the year Professor E. J. Goddard gave a lecturette on "Bunchy Top of the Banana."

The Council wishes to acknowledge generous subsidies amounting to £104 19s from the Queensland Government towards the cost of printing the Proceedings of the Society. Appreciative acknowledgment is also expressed to the University of Queensland for housing the library and providing accommodation for meetings. The library has been removed to a room adjacent to the University library, and has been reorganised.

The membership roll consists of four corresponding members, six life members, 173 ordinary members, and three associates. During the year ten new members were elected. The deaths of Professors Liversidge and Rennie (corresponding members) and Dr. W. F. Taylor (a trustee) are reported with regret. Messrs. F. Bennett, B.Sc., and J. B. Henderson, F.I.C., and Dr. A. J. Turner were elected Trustees of the Society.

There were ten meetings of the Council. The attendance was as follows—E. W. Bick 10, W. H. Bryan 7, J. V. Duhig 5, E. J. Goddard 7, R. W. Hawken 5, D. A. Herbert 9, H. A. Longman 3, E. O. Marks 9, T. Parnell 8, H. C. Richards 7, C. T. White 8.

E. J. GODDARD, President

D. A. HERBERT, Hon. Secretary

THE ROYAL SOCIETY OF QUEENSLAND

STATEMENT OF RECEIPTS AND EXPENDITURE FOR YEAR ENDED 31ST DECEMBER, 1927

RECEIPTS		EXPENDITURE	
£	s d	£	s d
Bank Balance, 31st December, 1926	3 11 3	Government Printer—	
Subscriptions	170 2 0	Volume and Abstracts	209 18 0
Government Subsidy, on Printing Account	104 19 0	Stationery Account	4 15 0
Sale of Reprints and Volumes, Proceedings	6 15 0	State Government Insurance	0 13 0
Exchanges	0 9 0	Hon Secretaries (Postages)	12 17 10
		Hon Librarian (Postages)	4 0 0
		Hon Treasurer (Postage and Duty Stamps)	2 0 0
		Lanternist (C Ihidge)	1 0 0
		Advertising	3 3 9
		Labour (Rearranging Library)	10 0 0
		Minute Book	0 7 6
		Exchanges and Stamps (Duty)	0 10 8
		Bank Charges	0 10 0
		Balance in Bank, 31st December, 1927	36 0 6
	£245 16 3		£285 16 1

Examined and found correct.

**H J PRIESTLEY, Hon Auditor,
25th February, 1928**

E W BICK, Hon Treasurer

ABSTRACT OF PROCEEDINGS, 19TH MARCH, 1928

Special Meeting

A Special Meeting was held in the Geology Lecture Theatre of the University at 7.40 p.m. on Monday, 19th March. The President, Professor E. J. Goddard, occupied the chair. On the motion of Mr. Longman, seconded by Dr. Marks, it was decided that Rule 15 of the Constitution of the Society be altered to allow of the appointment of two editors instead of one.

Annual Meeting

The Annual Meeting of the Society was held in the Geology Lecture Theatre of the University at 8 p.m. on Monday, 19th March, 1928.

His Excellency the Governor, Sir John Goodwin, occupied the chair. Apologies were received from Mr. G. H. Barker and Dr. Hamlyn Harris.

The Minutes of the previous meeting were read and confirmed.

The Annual Report and Financial Statement were adopted.

The following officers were elected for 1928 —

President Professor T. Parnell, M.A.

Vice-Presidents Professor E. J. Goddard, B.A., D.Sc. (*ex officio*),
and Professor J. P. Lawson, M.A., M.D.

Hon. Secretary Mr. D. A. Herbert, M.Sc.

Hon. Librarian Dr. J. V. Duhig, M.B.

Hon. Treasurer Mr. E. W. Bick.

Hon. Editor Mr. H. A. Longman, F.L.S., C.M.Z.S.

Hon. Auditor Professor H. J. Priestley, M.A.

Members of Council Professor R. W. Hawken, B.A., M.E., M.Inst. C.E., Dr. T. G. H. Jones, A.A.C.I., Dr. E. O. Marks, B.A., B.E., M.D., Professor H. C. Richards, D.Sc., and Mr. C. T. White, F.L.S.

Dr. O. S. Hirschfeld was unanimously elected as an ordinary member.

Mr. T. A. Williams and Mr. W. W. Bryan were proposed for ordinary membership.

Professor T. Parnell was inducted to the position of President for 1928, and Professor E. J. Goddard delivered his Presidential Address entitled "Virus Diseases Then Bearing on the Cell Theory and other Biological Concepts." On the motion of Mr. H. A. Longman, seconded by Dr. J. V. Duhig, a vote of thanks was accorded the retiring president for his address. A vote of thanks to His Excellency the Governor was carried on the motion of Professor H. C. Richards, seconded by Mr. J. B. Henderson.

The Council has received a letter from Dr. E. O. Marks, Hon. Secretary, Great Barrier Reef Committee, University, Brisbane, and,

as this is of special interest, it is communicated for the information of members who may desire to co-operate

Dear Sir

In reference to the expedition to the Great Barrier Reef which is expected to arrive from England in July and which has the full support and co-operation of this Committee, I am directed to enclose copy of a memorandum containing the latest details to hand

Both the English Committee and the leader of the expedition, Dr Yonge, have repeatedly expressed their desire for the co operation of Australian workers in marine biology. Unfortunately the funds will not permit of offering any salary. It is hoped by this Committee, however, that the unique opportunity for combined scientific work will be taken advantage of by research workers and institutions interested in marine biology. My Committee would be glad to hear if your institution desires to send a representative to work in conjunction with the expedition or can recommend any research student or other worker who may be desirous of joining the expedition.

Yours faithfully,

F. O. MARKS, Hon. Secretary

To the Hon. Secretary
Royal Society of Queensland

Addendum—In accordance with the alteration to rule 15, made at the special meeting on 19th March, 1928, Dr W. H. Bryan, M.C., was appointed co-editor by the Council of the Society.

D. A. HERBERT, Hon. Secretary

ABSTRACT OF PROCEEDINGS 30TH APRIL, 1928

The Ordinary Monthly Meeting was held in the Geology Lecture Theatre on Monday, 30th April, 1928, at 8 p.m.

The President Professor T. Parnell in the chair, and about forty members present.

An apology for absence was received from Mr C. T. White.

The minutes of the previous meeting were read and confirmed.

Messrs T. A. Williams and W. W. Bryan were elected ordinary members of the Society.

Messrs W. J. Chamberlain, M.Sc., Inigo Jones, and T. Rimmer, M.Sc., were nominated for ordinary membership.

A paper entitled "*Cinnamomum Laubatu*—The Chemical Characters of the Essential Oils of Leaves and Bark," by T. G. H. Jones, D.Sc., A.A.C.I., and F. B. Smith, B.Sc., F.I.C., was read by Dr Jones, and commented on by Professor H. C. Richards and Messrs Herbert and Henderson.

Dr J V Duhig read a paper on "Investigations into Sewage Pollution of the Brisbane Estuary" As the result of investigations over the period of five months, he reached the following conclusions —

(1) The present method of disposal of sewage into the Brisbane River estuary is not a nuisance

(2) The sewage as discharged contains solid matter only in a very finely divided state

(3) The bacterial content of the sewage is reduced with very great rapidity

(4) The power of the water of the Brisbane estuary to render sewage innocuous at present is many multiples of its used power in this respect

(5) The volume of water in the Brisbane estuary can effectually sterilise, at a minimum twenty-four hours, effluent within the time estimated at four hours from cessation of discharge at the outfall, even at a maximum depth of 4 feet of water

(6) Shallow water is not as good a diluent for sewage as deep water

(7) Onshore winds blowing on shallow water hinder dispersion and dilution

(8) Sewage disposal would be greatly improved by continuation of the outfall into deeper water. The optional length of this continuation would be a function of the grade of the channel and could only be determined by sounding experiments

(9) At present the method of disposal is economically sound and perfectly safe, provided that no sea food is taken from the shore 800 yards above and below the outfall sewer, at a distance of 50 yards from high water mark

(10) The most perfect hygienic result can be obtained by sewage discharge lasting from the end of flood tide until within an hour of the end of the ebb tide

(11) All these conclusions may be altered by large increases in the volume of the discharge

The paper was discussed by Professor Hawken and Messrs Henderson and Longman, and the President

Mr S B Watkins exhibited a fasciated rose stem which, on pruning, had given rise to normal shoots

Mr H A Longman exhibited a cast of the fossil Galilee skull, the original of which was found in a cave near the Lake of Galilee in 1925, and was the first skull of the Neanderthal type to be found outside Europe. The Galilee skull consists of the frontal part of the brain-case, with incomplete facial bones. The skull was narrow and high-vaulted,

and the bones were not so thick as in characteristic Neanderthal fossils. In some respects this fossil approaches the Australian aboriginal

Mr H Tryon commented on the exhibit

Mr D A Herbert exhibited specimens of haustoria of *Kroocarpus humifusus*, a Tasmanian hemi-parasitic flowering plant. The specimens were collected for the first time in National Park, Tasmania, in January, 1928

ABSTRACT OF PROCEEDINGS, 26TH MAY 1928

The Ordinary Monthly Meeting was held in the Geology Lecture Theatre of the University on Monday, 28th May, 1928, at 8 p.m.

The President, Professor T Parnell, in the chair, and fourteen members present. Apologies for non-attendance were received from His Excellency the Governor, Dr J V Duhig, and Mr D A Herbert.

Messrs W J Chamberlain, M.Sc., Iugo Jones, and T Rimmer M.Sc., were elected ordinary members of the Society.

Mr F W Moorhouse, B.Sc., was nominated for ordinary membership by Mr D A Herbert, and Mr R C Cowley by Dr J V Duhig.

Mr A P Dodd, in a few introductory remarks, tabled a paper on the "Revision of Four Genera of Scelionidae."

Mr A P Dodd also delivered a very interesting lecture on "Prickly-pear Insects." In outlining the subject he pointed out that the Prickly-pears (*Opuntia* spp.) had been introduced into Australia without their natural enemies. Owing to this, and to favourable climatic conditions, they had spread rapidly and become a pest. In their native habitats, Southern North America and South America, the various forms of prickly-pear were kept in check by natural enemies in the shape of insect pests.

The Prickly-pear Board has concentrated its activities on investigating insects adversely affecting the pear and on introducing those found the most effective. On arrival they are carefully tested by laboratory and field experiments to ascertain whether they will attack economic or other plants as well as members of the *Opuntia* family.

Mr Dodd gave an interesting review of the introduction, breeding, testing and liberation of insects, and he stated that so far the Indian cochineal and cactoblastus had proved the most effective, and with the aid of these insects the prickly-pear was now held in check from spreading, and there is every probability of its gradual extermination.

Mr C T White, in proposing a vote of thanks to the lecturer, paid a tribute to the good work being carried on by Mr Dodd and his staff. Mr J B Henderson, in seconding the motion, outlined the events leading to the formation of the Prickly-pear Board, and gave instances of the very effective work of pear destruction.

ABSTRACT OF PROCEEDINGS, 25TH JUNE, 1928

The Ordinary Monthly Meeting was held in the Geology Lecture Theatre of the University on Monday, 25th June, 1928, at 8 p.m.

The President, Professor T. Parnell, in the chair, and eighteen members present. Apologies for non-attendance were received from His Excellency the Governor, Professor Richards, Dr. Whitehouse, and Mr. Tryon.

Messrs. F. W. Moorhouse, B.Sc., and R. C. Cowley were elected ordinary members of the Society. Mr. L. L. S. Barr was nominated for ordinary membership by Mr. W. C. Dormer and Dr. John Bostock, M.B., B.S., D.P.M., M.R.C.S., L.R.C.P., by Mr. H. A. Longman.

The President announced that at a special meeting to be held on 16th July Sir Arnold Theiler would deliver a lecture on "Problems of Phosphorus Deficiency in Stock."

Mr. W. D. Francis read a paper entitled "The Location of Saponin in the Foam Bark Tree (*Jagera pseudo-rhus*)."

The bark of the foam-bark tree was a commercial commodity in Australia before the war. It was used as a substitute for quillaja bark which produces a head or foam on cordials. The foam-bark tree is found in the scrubs or rain forests of the coastal part of Australia from the Richmond River in New South Wales to the Barron River North Queensland. The frothing of infusions of the bark is due to saponin. As a result of anatomical and micro-chemical studies of the various parts of the tree the investigator found saponin to be concentrated in certain parts of the outer bark of the stem and root, in the wood of very young twigs, in the walls of the fruit, and in the recently formed wood of the root and stem. The chlorophyll-containing tissue of the leaves do not contain saponin and it is therefore indicated that the saponin is not a direct product of photosynthesis. The concentration of saponin in the cell walls in almost all cases suggests that it is concerned with the construction or composition of the cell walls. The frequent occurrence of saponin in association with hardened tissue suggests that it may be especially connected with the elaboration of woody tissue. The paper was discussed by Messrs. Dormer, Bennett, White, and Longman.

A paper by G. H. Hardy entitled "Revisional Notes on Described Australian Robberflies of the Genus *Ommatius*" was communicated by the Hon. Secretary. The paper was accompanied by specimens referred to in the text.

Mr. C. T. White exhibited specimens of 32 species of Basidiomycetes, mostly Polyporaceae, collected on Dunk Island by Mr. W. C. Dormer in May, 1927. As some of these have not hitherto been reported from the State, it is intended to publish the list.

Mr. H. A. Longman exhibited (a) fossil Dicotyledonous leaves from Mr. A. Arthur's property, Coolabunia, seven miles from Kingaroy, and (b) two molar teeth and the fragment of a mandible of *Macropus anak*.

found 40 feet below the surface in a well by Mr D. Salisbury at Knapp's Creek, near Beaudesert. The exhibits were discussed by Dr W H Bryan and Dr George Parker.

ABSTRACT OF PROCEEDINGS, 27TH AUGUST, 1928

The Ordinary Monthly Meeting was held in the Geology Lecture Theatre on Monday, 27th August, 1928, at 8 pm

The President, Professor T Parnell, in the chair, and about thirty members present

The Minutes of the previous meeting were read and confirmed. Mr L L S Barr and Dr John Bostock, MB, BS, DPM, MRCS, LRCP, were elected ordinary members of the Society.

The President referred to the death of Mr W R Colledge, and expressed the Society's appreciation of his work.

Professor H C Richards communicated a paper entitled "A Geological Reconnaissance of Part of the Aitape District, Mandated Territory of New Guinea," by H G Raggatt, BSc, of the Department of Mines, Sydney. The general geographical features of the area are as follow: (1) The Coastal plain is about one mile wide at Uluu, and reaches a maximum of approximately 12 miles at Sissano. It is so little raised that the streams which flow through it inevitably meander as they approach the sea in some places forming deltas with numerous distributaries. With the exception of Vanimo, there are no deep water bays of importance. (2) The Coastal foothills are a well-defined area between the plain and the main dividing range, and have an average height of about 500 feet. The streams are relatively swift flowing and deeply entrenched. (3) The Dividing Range here does not exceed 5,000 feet in height and is enclosed in thick jungle. (4) The Inland slopes, populated by the Wa-pi tribe, are little known.

The rocks exposed were provisionally classified. They include pre-Cretaceous schists and gneisses of the main dividing range, pre-Miocene (possibly Mesozoic) altered sediments, Tertiary (probably Miocene) beds of blue micaceous mudstone alternating with shale and sandstone, and of limestone, late Tertiary (probably Pliocene) beds of limestone, volcanic rocks, conglomerate, sandstone, and agglomerate, recent and Pleistocene estuarine and river beds, river gravels, sands, and muds. Palaeontological notes were supplied by Messrs Tom Iredale and W S Dun. It was suggested that the search for oil be confined in the first place to locating suitable structures in beds of Miocene age which have not been too highly folded or much intruded by igneous rocks. The paper was discussed by Sir Edgeworth David, Mr J H Reid, and Dr E O Marks.

Professor H C Richards exhibited a specimen of clay shale with a curious chocolate iron-staining pattern. The specimen, which was forwarded by Mr T Blatchford, the Government Geologist of Western Australia, has a very unusual pattern which, owing to its regularity and nature, suggests a possible organic origin. It came from a locality 80 miles south-east of Wyndham, Western Australia, and underlies the Salterella beds. Mr Blatchford has obtained other

specimens of similar pattern in the Braemar area from the Nullagine series. The finder is anxious to have an adequate explanation of the origin of the pattern, and hopes that such may possibly help in fixing the age of the Nullagine beds more accurately.

Professor Richards also exhibited precious opal from a quarry in the Brisbane tuff at Kedron. This was forwarded by Mr Huxham, an engineer of the Brisbane City Council, and had been obtained during quarrying operations from "porphyry" metal. The exhibits were commented on by Dr Bryan, and an informal discussion took place.

The Council wishes to draw the attention of members of the Society to an announcement by the Royal Society of New South Wales that a prize, known as "The Walter Burfitt Prize," has been established by that Society. The prize is awarded at intervals of three years to the worker in pure or applied science, resident in Australia or New Zealand, whose papers and other contributions published during the past three years are deemed of the highest scientific merit, account being taken only of investigations described for the first time, and carried out by the author mainly in these Dominions. The prize consists of a medal and the sum of £50, and may be awarded to two authors working in collaboration. The first award will be made in May, 1929, and nominations and publications should be submitted to the Royal Society of New South Wales not later than 28th February, 1929.

D A HERBERT,
Hon Secretary

ABSTRACT OF PROCEEDINGS, 24TH SEPTEMBER, 1928

The Ordinary Monthly Meeting was held in the Geology Lecture Theatre of the University on Monday 24th September, 1928, at 8 pm.

The President Professor T Parnell, in the chair and about forty members present.

~~The minutes~~ of the previous meeting were read and confirmed. Miss M E Lethbridge was nominated for ordinary membership by Dr J V Duhig.

Professor R W Hawken, B.E., read a paper on "Stress Transmission in Frictional-cohesive Material." This was an inquiry into the question of stress transmission in material other than fluids. Fluid pressure was taken as the fundamental law, and the change in stress throughout the material arising from potential frictional and cohesive resistance to shear, separately and conjointly, were expounded. The author's method goes on the assumption that the cohesive resistance is independent of previously existing stress equilibrium for non-cohesive material. Consequently, in computation cohesion is treated as an independent shear introduced as a maximum on a plane with corresponding shears on all other planes. The plane on which the shear c is introduced will be the Critical Plane of Equilibrium. In the ellipse of stress deduced, the active shear on the critical plane is equilibrated by the potential resistance to shear due to both frictional and cohesive

resistance. The outstanding factor of the analysis set out is that the principal planes for frictional-cohesive material differ necessarily in direction from those for the same loading, presuming no cohesion. In the author's view, the theories of Rankine (earth pressure), of Navier (failure in compression), and of Guest (failure by shear) are special limiting cases. Those of Scheffler (unsupported banks), Ketchum (trench cutting), Bell (pressure in clay), and any straight line wedge theory for cohesive material have the same basic error—namely, that a limiting condition, impossible practically, is assumed as existing for the general case. The author's view being at variance with accepted theories, the reasons were discussed from several aspects and illustrated by examples, theoretical and practical. The paper was commented on by the President and by Dr E O Marks.

Dr R Hamlyn-Harris read a paper entitled "Notes on the Breeding Habits of *Culex fatigans*, Wied., and its Associated Mosquitoes in Queensland." *C. fatigans* is found associated with nine different species of mosquito in the Greater Brisbane area, the association being dependent to a very large extent upon the state of the water at the time of selection. There exist cyclic variations due to rain and atmospheric conditions in which temperature and humidity play an important part. The study of hydrogen ion concentration within certain limits of waters selected for breeding purposes does not throw any light on the reason for selection, but serves only as an indication of the type of water preferred by certain kinds of foodstuffs or organisms or aquatic vegetation, as the case may be. There is considerable mortality among the developmental stages of *C. fatigans* at all times, but especially during hot summer weather. It is surmised that this is due either to a kind of intoxication or narcotic poisoning or to the toxic nature of the decomposition products, especially in acid by the high temperature. Investigations into the breeding of mosquitoes in the Brisbane cemeteries lead to the belief that *C. fatigans* and *Aedes notoscriptus* choose the artificial receptacles on graves more so than other mosquitoes and use them to the full extent of their power. *C. fatigans* holds undivided sway in some cemeteries, *A. argenteus* choosing vessels near human habitations for preference. It is surmised that *Mucidus alternans* and *Aedes vigilax* select fresh water only from compulsion being both by nature salt marsh mosquitoes. Charophyta do not thrive in pollution, and hence when mosquito larva occur with *Nitella* they are usually *A. annulipes*, and sometimes other sylvan species rather than *C. fatigans*. Under laboratory conditions however, it is quite a common thing for *C. fatigans* to lay egg rafts upon *Nitella* water. The size of the egg rafts of *C. fatigans* is entirely dependent upon the state of maturity of the female. Though the presence of food seems to be the determining factor in the selection of breeding places the quantity and quality of the decomposition products in the water may be said to be the main determining factors with regard to the measure of retardation in development of *C. fatigans*.

Under laboratory conditions eggs sometimes fail to produce larvae, and it is surmised that infertile females even though possibly fed on blood, produce infertile eggs. The possibility of the septic tank as a breeding ground for *C. fatigans* must be recognised. Pollution from tanneries is responsible for enormous numbers of *C. fatigans*, though tan liquor pits are far too acid for selection. The paper was discussed by

Dr J V Duhig, Mr F A Perkins, Dr E O Marks, and Mr W J. Chamberlain

A paper entitled "The Essential Oil of *Eucalyptus Andrewsii* from Queensland," by T G H Jones, D Sc, A A C I and M White, B Sc, was laid on the table. A eucalypt common on the road between Toowoomba and Crow's Nest, named by Mr C T White as *E hamastoma* var *inophloea*, but considered by him as probably referable to *E Andrewsii*, was shown on the evidence of its essential oil to belong to the latter species.

ABSTRACT OF PROCEEDINGS, 29TH OCTOBER, 1928

The Ordinary Monthly Meeting was held on 29th October, 1928, at 8 p.m., in the Geology Lecture Theatre, University. The President, Professor T Parnell, in the chair, and about twenty-five members present. Apologies were received from Dr Marks and Professor Richards.

The minutes of the previous meeting were read and confirmed. Miss M E Lethbridge was elected to ordinary membership of the Society. A paper entitled "Petroleum from the Roma Bores" by J B Henderson, F I C, and W J Wiley, M Sc, was communicated by the senior author. This was an account of the work undertaken at the Government Chemical Laboratory, and an historical account of the investigations was given. The experimental work on a sample of Roma oil received in November 1927 involved a fractional distillation of the oil, and the determination of the vapour pressure, vapour density, and specific gravity of the fractions. The results were presented in tabular form, and samples exhibited. Dr L S Bagster, Mr Reid, and the President discussed the paper.

Dr W H Bryan communicated a paper by Mrs C Biggs on "The Brisbane Tuff." The paper dealt in some detail with the field occurrence and petrological characters of that formation. Chemical analyses of typical samples of the tuff were given and compared with chemically similar rocks in Australia and elsewhere. The age and origin of the Brisbane tuff were fully discussed, and a hypothesis was advanced as to its relationship with the various late Palaeozoic and Mesozoic igneous rocks of Southern Queensland. The economic value of the formation was also considered. Messrs Denmead and Inigo Jones and Dr Bryan discussed the paper, and appreciative comment was made by letter by Professor Richards.

ABSTRACT OF PROCEEDINGS, 26TH NOVEMBER, 1928

The ordinary monthly meeting was held in the Geology Lecture Theatre of the University on Monday, 26th November, 1928, at 8 p.m.

The President, Professor T Parnell, in the chair and twenty members present.

The minutes of the previous meeting were read and confirmed

Mr D A Herbert, M Sc, read a paper entitled "The Major Factors in the Present Distribution of the Genus *Eucalyptus*." Most of the species of *Eucalyptus* are located round the coast in a belt about 200 miles wide. Isolation of Tasmania and south-western Australia has resulted in a high proportion of endemism. This high endemism is not a proof of great age. Most of the eastern eucalypts are temperate, the total numbers and numbers of endemics decreasing north of Maryborough. Taking the whole of Australia, there are 30 species of narrow and 37 of wide range in the tropics, the figures for the temperate zone being 202 and 92 respectively. The number of species decreases rapidly as the arid regions are entered, and the endemism is also less marked except on the Western Australian goldfields, where the success of the *E. olcosa* and *E. murrasata* groups has raised the figures considerably. Boreoan species such as *E. diversifolia*, *E. Flotowiae*, etc., which are found in east and west but not in central Australia, are regarded as relics. The bloodwoods were shown to be the descendants of a surviving fringe of forms which have retreated from the more central parts, and the same is true of the *Endemium*. Evidence was presented to show that there has been a retreat of the bloodwoods from the south, followed by a re-invasion from the north. The extra-Australian eucalypts are emigrants, and the genus is a comparative failure in Malaysia owing to climatic factors. Present day eucalypts avoid the arid tropics, the extremely moist tropics, the arid temperate regions, and the cold of the mountain tops. In the favourable parts of the tropics their numbers are very small as compared with those of similarly watered temperate areas. It is concluded that the genus *Eucalyptus* at the present day is a development of the fringe of species which remained round the coast after the destruction of the greater number of the species as the central part of the continent became more arid, and that the early eucalypts established themselves in the well-watered temperate portions of the continent. The paper was discussed by Messrs C T White, W D Francis, and Inigo Jones.

Mr H A Longman exhibited a juvenile specimen of *Epueratodus forsteri*, 145 mm in length, which was one of a series secured alive from Enoggera Reservoir. The discovery of these juvenile lung-fishes was of interest to members, as they were the progeny of the large specimens placed in the reservoir in 1895-1896 by the late D O'Connor under the auspices of the Royal Society of Queensland. A detailed report appears in "Memoirs of the Queensland Museum," vol ix, part 2, pp 160-173.

Publications have been received from the following Institutions, Societies, etc., and are hereby gratefully acknowledged.

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LIST OF MEMBERS

Proceedings of the Royal Society of Queensland.

Presidential Address.

By PROFESSOR T. PARNFIL, M.A.

(Delivered before the Royal Society of Queensland, 25th March, 1929)

As is shown in the annual report submitted by your Council the Royal Society, during the past year, has continued to perform successfully the function for which it was founded—"the furtherance of the natural and applied sciences, especially by means of original research"—for thirteen papers on various branches of science were read and published. The thanks of the Society are, I think, due to our two co-editors, Dr. Bivan and Mr. Longman, for the very efficient manner in which they have performed the onerous duty of seeing these publications through the press.

Another important activity entailed in this function is the bringing together of people interested in scientific work and here too, the Society has had a successful year, for members have had opportunities of meeting and hearing several very distinguished visitors. In this connection, also, I should like to mention the library, for, apart from our monthly meetings, it constitutes the only direct bond of union between members of the Society. Our very valuable and useful collection of books and journals is now housed in a convenient room, and tables and chairs and extra shelving have been provided with a view to making a more comfortable and convenient reference library. It is hoped that members will take advantage of the improvements and by a more general use of the library add to its value as a direct aid in the advancement of science, and as a common meeting ground for members of the Society.

Despite the expenditure on the library, the balance-sheet shows that the finances of the Society are in a satisfactory condition, and in this connection I should like, with your permission, to record our appreciation of the very efficient and untiring services of our treasurer, Mr. Bick.

It is my sad duty to record the deaths of three of our members.

Mr. William Robert Colledge died on 26th August, 1928, at the age of eighty-six. Though born in England, he spent the greater part of his life in Queensland, where he held the position of manager of the Brisbane 'Associated Friendly Societies' Dispensaries. His leisure time was devoted

to the study of natural history and he was a recognised authority on rotifers and mosquitoes. An active supporter of the Royal Society, he held the position of President in 1910, and between 1900 and 1925 he contributed ten papers to our Proceedings. Himself an enthusiastic worker, he spared no effort in helping to interest others in natural history, and his loss will be deeply felt by this and kindred societies.

Dr Jiri Vaclav Daněš, Professor of General Geography at the Charles University of Prague, was killed in a motor accident on 13th April at Los Angeles. In the course of his extensive travels, he visited Australia and was made an honorary member of the Royal Society of Queensland in 1910, since when he has continued to be a corresponding member. In 1919 he was appointed to a professorship at Prague, but, soon after, he left to take the post of Consul-general in Sydney and during this second visit he continued his scientific work in Australia. He was the author of numerous publications, and by his untimely death at the age of forty-eight the world has lost one of its leading geographers.

Mr Rowland Illidge, a past member of the Society, died on 17th February, 1929. He was born in England, but came to Brisbane at the age of nine. He was appointed a pupil teacher in 1868 but left the Department of Public Instruction in 1876, and after short service in the Railway Department he became associated with the South British Insurance Company, and later with the Commercial Union Assurance Company. He was a prominent member of the Queensland Naturalists' Club, and published many papers in the journal of that Society.

MODERN DEVELOPMENTS OF PHYSICAL SCIENCE

As the main topic of this Presidential Address I shall attempt to review, from certain aspects, the development of Physical Science during the past few decades, that is, during the period of transition from "classical" to "modern" physics. This period has been one of great activity in all branches of the subject, in the applied as well as in the experimental and theoretical.

The general public is inclined to over-estimate the importance of the technical side of science, to regard for instance wireless, X-rays, and motor cars as denoting the important achievements of physical science, and perhaps for this reason there is sometimes a tendency for the worker in pure science to depreciate the technical side of his subject. While essentially of secondary importance, technical science plays an important part in the development of pure science, for technical problems frequently require for their solution research work that yields results of value in pure science, and technical applications make available to the research worker instruments and appliances which make possible or greatly facilitate his experiments. More important still, the resulting demand of industry for men trained in scientific research adds very materially to the attractiveness and possibility of a scientific career, and so largely increases the number of research workers trained and interested in pure science. This fruitful co-operation between pure and applied physics and industry is growing, pure physicists are being employed in industry

to an increasing extent, and members of the staffs of the research laboratories of manufacturing companies are publishing many valuable papers on pure Physics

Of the experimental work in Physics two features call for comment the enormous output resulting from the discovery of electrons, X-rays, radioactivity, &c, and the increase in the accuracy and in the range of experiment, due in part to the natural improvement in technique that comes with experience, and in part to the improved experimental facilities resulting from the collaboration of the physicist engineer, chemist, and instrument maker

For instance, the absolute measurement of resistance is a measurement of great practical importance and has therefore been the subject of many investigations, about 1890 the probable error in the measurements was of the order of 1 in 2 000, in 1913, 2 in 100,000. Again, in 1913, X-ray wave lengths could be measured in terms of the lattice constant of rock salt with a probable error of about 1 per cent to-day the probable error is estimated at a few parts in 100,000

Electro-magnetic radiation furnishes a good illustration of the extension of the range of experiment. Prior to the discovery of Hertzian waves in 1886 and X-rays in 1895, our knowledge of radiation was limited to the visible spectrum and a short distance into the infra red and the ultra violet. To-day the gaps between the Hertzian waves and the infra red on the one side, and between the ultra violet and X-rays on the other, have been filled in, and radiation is investigated over the whole range of wave lengths from more than 20 000 metres in the case of the waves used in wireless telegraphy, down to less than 0.2×10^{-8} cm in the case of hard X rays

The new knowledge gained by experiment has necessitated profound modifications of physical theories, and it is these modifications and especially the corresponding change in the outlook and the attitude of mind of physicists, that I wish to discuss

Let us consider the position of classical physics towards the end of last century. Taking for granted the ideas of space, time, and either matter or energy, and assuming certain properties of a universal medium named the ether, it had been possible, by experiment combined with inductive and deductive reasoning to build up what promised to be a complete description of physical phenomena. New phenomena could be described in terms of known phenomena already described in terms of the fundamental ideas, phenomena could be grouped together by scientific laws, which again could be inter-connected by physical theories, thus the dynamical theory of heat brought thermal phenomena within the realm of mechanics, and the electro-magnetic theory of light successfully connected optical and electrical phenomena. It seemed possible, therefore, that one comprehensive dynamical theory might be formulated which would embrace the whole range of physical phenomena. Certain difficulties existed, for no set of physical properties adequate to explain experimental facts could be assigned to the ether, and as a consequence

it was not found possible to give a purely dynamical explanation of electrical phenomena. In this connection the following extract from a speech by Kelvin delivered during his jubilee celebrations in 1896 may be quoted —

“One word characterises the most strenuous of the efforts for the advancement of science that I have made, perseveringly, during fifty-five years, that word is ‘failure’ I know no more of electric and magnetic force or of the relation between ether, electricity, and ponderable matter than I know and tried to teach to my students of Natural Philosophy fifty years ago in my first session as Professor”*

That the word “failure” refers only to the final result of these particular efforts, and must not be accepted as a criticism of the value of Kelvin’s work, is made clear in the following statement by the late Professor Fitzgerald —

“Though he himself has described these efforts as resulting in ‘failure’ his contemporaries and disciples see a succession of brilliant successes, which have not, indeed, fully conquered the citadel of ignorance against which they were directed, but have nevertheless conquered many and fair districts, and advanced the armies of knowledge in their reconnaissance of this citadel to an extent that was only possible for a great general, an indefatigable and enthusiastic genius”†

Physics had been developed as an exact science. Starting with the fundamental assumptions, by accurate reasoning, experimental facts were co-ordinated by scientific laws which were confirmed by repeated experimental tests both direct and indirect and these laws were co-ordinated by the accepted theories which made as few assumptions as were necessary for their effective use, and moreover these assumptions were as simple as possible, the aim being to explain the more in terms of the less complex. Mechanics appeared to be the simplest and most fundamental of the branches of physics, hence the numerous unsuccessful attempts to design mechanical models of the ether and so to formulate purely mechanical theories of light and electricity and magnetism.

This apparent exactness of classical physics we now believe to have been illusory. Ultimate truth is without meaning when considering scientific theories, the only test of a scientific theory or of a scheme of scientific description is consistency and adequacy, for, of two schemes mutually contradictory but individually consistent and adequate, it is impossible to say that one is right and the other wrong. Now certain observed facts obstinately refuse to fit into the classical scheme, which is therefore found to be inconsistent. If the building of the scheme is accurate, then the inconsistency must be due to the foundations, and critical examination has found this to be the case. Naturally, physical

* Life of Kelvin, p. 984

† Life of Kelvin, p. 1085

laws have been but very slightly modified by the necessary adjustment, for these were, and are, direct statements of observed results within the accuracy of experiment, but fundamental ideas and physical theories have been profoundly altered

Towards the end of last century the discovery of X-rays and radio-activity, and the rise of electron theory, opened up a new and wide field for research. This pioneer work naturally lacked the accuracy of the older work both in experiment and in theory. Measurements were rough, and laws and theories were formulated that only very roughly agreed with experimental results and that sometimes were mutually inconsistent. In fact, superficially, it appeared as though physics had ceased to be an exact science. This was a necessary phase of development, for rough measurements prepare the way for more exact measurements and rough theories are tentative and temporary, they suggest lines of experimental research and assist in the evolving of the more accurate theories that replace them.

One effect of this phase was, I think, a general stimulation of scientific imagination. Strict orthodoxy was no longer possible, and the minds of physicists in general were thus prepared for revolutionary attacks on fundamental principles of classical theory. The nature of these attacks and the changes which have followed are best illustrated by considering briefly the more striking developments.

In 1881, J. J. Thomson had proved theoretically that a moving charged particle possesses additional kinetic energy, and therefore additional mass, by virtue of its electric charge. The discovery of electrons and the measurement of their mass and charge gave particular importance to this conclusion, for the fact that the measured mass of the electron was very much less than that of the lightest atom suggested that the mass of the electron was entirely electrical, and as a further extension that all mass was electrical in origin. Now calculation, according to classical theory, showed that the electrical mass of a charged particle increases with its velocity, a conclusion that was subsequently proved correct by the experimental measurements of Kauffmann and Bucherer. Not only did mass, being variable, thus lose its fundamental character as a measure of matter, but it actually became indeterminate, for absolute velocity has no physical significance, only velocity relative to some fixed frame can be measured and the Michelson-Morley experiment, which had failed to detect any motion of the earth relative to the ether, appeared to make it impossible to regard the ether as such a fixed frame of reference. Here then was a fundamental difficulty the removal of which involved modification of the foundations of classical physics, and such a solution was forthcoming. Lorentz, starting with those general equations of the electro-magnetic field which are the foundations of the electro-magnetic theory of light, considered two systems in relative motion and found that, by making certain transformations, the form of the equations became the same in either system, that is to say, an observer in *either* system would observe electrical phenomena taking place in *both* systems according to the general equations, but the observed

magnitude of a particular length or time must be different for the two observers, in order to preserve this sameness of electro-magnetic equations. Thus, assuming an electron to be spherical when at rest relative to an observer, when in motion it would, as measured by him, be contracted in the direction of its velocity, and its observed electric field would differ from the field observed when at rest. In terms of his transformations Lorentz found expressions for the mass of a moving electron which are in good agreement with experimental measurements made at a later date (1909) by Bucherer.

Einstein started from a different point of view, he examined the principles of length and time measurements, and showed that the existing ideas were indefinite and inadequate, but, assuming the velocity of light in empty space to be constant, he showed that a consistent scheme resulted if existing ideas of space and time were replaced by the ideas implied in the Lorentz transformations, and thus he laid the foundation upon which he developed his theory of relativity.

The revolutionary nature of this theory is at once apparent. Mass loses its essential characteristic of constancy, and matter ceases to be a fundamental entity, time and space can no longer be regarded as having independent existence and our three-dimensional space with time as an independent variable is replaced by a four dimensional world in which time and space are interrelated. In this four dimensional world, as developed by Einstein and Minkowski, our ordinary perceptual ideas of physical phenomena disappear, and only the highly expert mathematician can find his way with certainty. The results of such excursions can, however, be interpreted in terms of physical phenomena and be subjected to experimental test.

Our former apparently simple concepts have, then, been replaced by more abstract and more complex concepts, but with the gain of definiteness and consistency. That the new concepts are more complex and more difficult of apprehension than the old is illustrated by the fact that many of the objections at first offered to the theory, and many of the proposed experimental tests, were based on fallacious reasoning resulting from the partial carrying over of the old ideas into the relativistic scheme.

Another feature of great significance has been the development of statistical methods of investigation and the fuller recognition of the statistical nature of many scientific laws, that is, the realisation that the regularity of the phenomena described, and therefore the accuracy of the laws, depends on the fact that the observed phenomena represent the average effects of an enormous number of events occurring in an irregular haphazard fashion. This development is a necessary outcome of atomic theories. Towards the end of last century, the atomic theory of the structure of matter and the dependent molecular and kinetic theories were indispensable to physicists and chemists, but it was impossible to observe directly the properties of an individual atom or molecule, so that "molecular reality" was still an open question. Since then

the investigation of electrons and gaseous ions has led to the theories of the atomicity of electricity and the electrical structure of the atom, moreover, owing to the great amount of energy possessed by certain ions it has been possible to observe the behaviour of individual particles, and thus the atomicity of matter and of electricity has been brought from the realm of speculation into the range of experimental knowledge.

Most of our experimental observations, however, are large scale observations concerned with very large numbers of atoms and so involving very large numbers of discrete phenomena they therefore deal with average effects only, and do not give us direct and unequivocal information as to the nature of the individual phenomena. The observed pressure and temperature of a gas are such average values representing the average effects of the motion of individual molecules, and the kinetic theory is a statistical investigation of the phenomena, making as few and as simple assumptions as possible as to the nature of the molecules and their encounters, it explains the properties of gases, but it does not give us an exact account of the dynamics of an individual encounter. An essential feature of such statistical investigation is the use of the laws of probability. It would be quite impossible, for instance, however simple our dynamical assumption, to investigate mathematically the history of any one molecule, but, by assuming that a number of occurrences are equally likely, we are able to calculate the most probable average properties of ordinary molar quantities of gas which contain very large numbers of molecules.*

As far back as 1877, Boltzmann had given an explanation of entropy in terms of probability and thus arrived at a statistical proof of the second law of thermodynamics, but the fuller development of this idea did not occur till the beginning of this century. The second law of thermodynamics deals with the transfer of heat, it states generally that the spontaneous transfer of heat is from hotter to colder bodies, and so asserts a general tendency towards equalisation of temperature. It is a law that is very readily applied to physical and chemical problems, and forms the basis of a vast amount of theoretical work, the conclusions of which are in agreement with experiment, so that it is regarded as a very general physical law of tested validity within its sphere of operation. If we extend its sphere of operation to include the whole universe, we arrive at the conclusion that a universal and continuous degradation of energy is taking place, and that the universe as a whole is moving towards a state of stagnation in which no further energy transfers are possible.

As a statistical law, however, based on probability, the second law of thermodynamics states the most probable results. Dynamically a slower moving molecule may give up energy to a faster molecule, and, from the point of view of dynamics, there is no reason why, in a vessel containing a gas, the faster moving molecules should not drift to one

* 1 cc of gas under normal conditions of temperature and pressure contains 27×10^{23} molecules.

side and the slower to the other, thus causing a measurable difference of temperature in the gas, just as there is no reason why a bridge player should not receive a hand consisting of thirteen spades every deal for ten years. In each case, however, probability calculations show that the odds against such an occurrence are so enormous as to make it unnecessary for us to take the possibility into practical consideration.

While, then, we can use the second law of thermodynamics with every confidence in the sphere of action proper to it, we cannot assume it to be of universal validity, we can only use it in relation to phenomena such that the laws of probability may be assumed to be valid.

Similarly, the atomicity of electricity indicates that our experimental laws in electricity and magnetism are statistical laws and that our practical measurements represent average values. Ohm's law, for instance, states the *large scale* experimental fact that, to a very high degree of accuracy, the current in a conductor is proportional to the electric force, on the *small scale*, the current consists of a drift of electrons and the electric force varies very rapidly from point to point inside the conductor, which itself becomes a structure of electric charges. Current and electric force therefore are measured only as average values, and though the statistical law is so simple no satisfactory theory has yet been advanced which describes the actual movements of individual electrons within the metal. An electric current, then, can no more have a constant value than can the number of sheep passing per second through a wide gate, the current may have a constant *average* value but fluctuations must exist, and, in some cases, it is possible to detect them experimentally. In a wireless valve, the electrons are emitted from the hot filament in haphazard fashion, and, for a steady average value of the anode current, fluctuations will be present whose nature and magnitude can be calculated in terms of probability. By means of a special amplifier, Hull measured these fluctuations and obtained results in good agreement with theory.

The first step in modern electrical theory is to ascribe to the electron and the proton, which are the "atoms" of electricity, the simplest properties which will account for our large-scale electrical laws. Now the basic laws of electricity and magnetism can only be accurately expressed in terms of mathematical analysis. For instance in calculating the force between two charged bodies by means of the inverse square law, it is necessary to consider the actual charges as built up of a large number of elements of charge. The obvious procedure, therefore, is to ascribe to electrons and protons the properties of such elements of charge, and so to assume that they will behave in accordance with the general laws of electro-magnetism. The validity of this assumption will be discussed shortly.

The behaviour of electrons and of charged atoms and molecules has also been studied by more direct methods, the deflections of such particles in electric and magnetic fields have been measured and the results of such experiments are consistent with the above assumption, provided that the necessary relativity corrections are applied in the case of the

faster moving particles. Again, during certain radioactive changes, charged helium atoms known as α particles are ejected with such high velocity that a single one impinging on a fluorescent screen produces a visible flash of light, or passing into a suitably arranged ionization chamber gives rise to a detectable amount of ionization, and thus direct observation of individual particles is possible. Observation shows that these particles are emitted in haphazard fashion, and that regularity only appears when average values are considered. This suggests that any one atom is just as likely to disintegrate as any other—that is, that the disintegration of the atoms is a chance occurrence, and that therefore the probable number disintegrating in any short interval of time will be a definite fraction of the whole number, from which the exponential law of decay is an immediate deduction. The experimental validity of the exponential law of decay thus confirms the result of direct observations, the regularity of the statistical law of decay confirms the assumption of irregularity or fortuitousness of the individual disintegrations.

The work of Rutherford and others on the scattering of α particles by matter also gives a good illustration of the direct use of statistical methods. A narrow beam of α particles was allowed to impinge on a thin sheet of metal foil, and the relation between the angle of deflection and the proportion of the whole number deflected to this extent was determined by direct counting. Assuming the inverse square law to hold for the force between an α particle and the nucleus or positive portion of an atom their shortest distance apart was calculated in terms of the angle of deflection, and by probability calculations, a formula was deduced giving the average distribution of the scattered particles. The agreement of observed results with the formula for a given range of angles of deflection was evidence, therefore, of the validity of the inverse square law for a corresponding range of distances. In this way it was possible to prove indirectly that the inverse square law holds at distances very small compared with the size of the atom, and therefore that the nucleus itself is very small—results of the greatest importance in theories of atomic structure.

This brief discussion of statistical laws is sufficient, I think to indicate certain general points of view.

Statistical laws, though of the greatest practical importance, from their very nature cannot be regarded as exact in the mathematical sense. It is common to hear physics described as an exact science and biology as inexact, the difference is one of degree, and the greater accuracy of physics is in part due to the fact that atoms and electrons are smaller and more numerous than the units of the biologist. Many methods of attack are common to both and we may expect in the future, at any rate in statistical science, even more mutual inspiration between workers in the two subjects.

Again, statistical laws, being based on probability, can only be expected to hold good when probability calculations are possible. that

is, for phenomena such that we may assume we are dealing with groups of large numbers of events all of which are equally probable. Any fresh influence therefore introduced into such a system may upset this equality and invalidate our conclusions. If, for instance, a homogeneous steel cube be tossed into the air and allowed to fall to the ground, we can state as a statistical law that for any large number of trials, N , a given face will be uppermost approximately $N/6$ times, and the larger N the greater the accuracy of the law. If, however, the cube were magnetised, the symmetry would be destroyed and this statistical law would no longer be valid. Until, then, it is definitely demonstrated that life and mind cannot be regarded as possibly constituting such influences, the physicist cannot assert that statistical physical laws will necessarily apply to biological phenomena.

Again, statistical laws are unsatisfying from the philosophical point of view, they give us the practical effects of a number of discrete events, but do not describe the individual events themselves. Working back from statistical laws we can find descriptions of the elemental events which are satisfactory as far as these laws are concerned, but we cannot assert that these descriptions are correct, for others might be equally satisfactory. We can, however, assert that a description is incorrect or incomplete if we find that in some new connection it leads to conclusions inconsistent with experience. As mentioned above, the assumption that individual electrons and protons behave in accordance with the general equations of the electro-magnetic field is consistent with the more basic experimental laws of electricity and magnetism and with such direct measurements on electrons and ions as have been possible, but the phenomena here involved are large-scale phenomena and we are not justified in expecting that the same description will necessarily be satisfactory for the atomic scale, and, in fact, all attempts to apply classical electro-magnetic theory to electrons within the atom have resulted in failure.

The problem of atomic structure affords a good illustration of this difficulty. A static atom built up of protons and electrons and having the nuclear structure demonstrated by Rutherford's experiments cannot be stable, while a dynamic atom consisting of electrons describing orbits about the nucleus as do planets round the sun is also impossible according to classical theory, for the electrons, having acceleration, would radiate energy and the orbits would therefore contract until the electrons fell into the nucleus, moreover, such an atom could not emit radiation corresponding to the sharp lines found in spectra.

A partial solution of the problem came from the development of quantum theory. About the beginning of this century Planck began his theoretical investigations of the radiation from hot bodies. He found that calculations based on classical theory gave results inconsistent with experiment, and was thus led to postulate a kind of atomicity of radiant energy. The basic assumption of the quantum theory is that radiant energy is emitted and absorbed not continuously but in definite

discrete "atoms" known as quanta, but unlike the "atoms" of electricity these quanta of radiant energy are not all equal, for the amount of energy in a quantum is equal to the frequency of the radiation multiplied by a universal constant known as Planck's quantum of action. This theory soon found other applications to hitherto unsolved problems such as the phenomena of photo-electric emission and the variation of the specific heats of solids with temperature but its most fruitful development commenced in 1913 when Bohr published a quantum theory of the structure of the hydrogen atom which accurately explained the observed relation between the frequencies of certain series of lines in the hydrogen spectrum.

Bohr's model of the hydrogen atom incorporated Rutherford's positive nucleus and consisted of a proton as nucleus with a single electron describing an orbit about it in accordance with the inverse square law of force, the path of the electron is therefore a circle or an ellipse, but at first Bohr only considered circular orbits. According to classical theory, any ellipse would be a possible orbit, its size depending on the total energy of the atom, and again in any orbit the electron would be radiating energy, but Bohr based his theory on three postulates which represent radical departures from classical theory. Planck's universal constant h has the dimensions of energy multiplied by time, that is, the dimensions of "action," which is a most important quantity in generalised mechanics. Bohr assumed—

- (i) that only those orbits are possible for which the "action" is a whole number multiple of h (for circular orbits this means that the angular momentum is $n\hbar/2\pi$),
- (ii) that these orbits are non-radiating,
- (iii) that radiation occurs when the electron passes from one orbit to another, and that the frequency of the radiation is given by $\nu \cdot h = E$, where E is the decrease in energy of the atom.

This theory has since been extended to include elliptic orbits and atoms with more than one extra nuclear electron, and has proved of the greatest value in introducing regularity and order into spectroscopy. In the spectrum of any element it is possible to select sets or series of lines whose frequencies show a simple arithmetical relation, and such spectral series occur in the infra red, the visible, the ultra violet, and in X-ray regions. Quantum theory not only explains such series, but also explains the effect on lines of electric and magnetic fields, and again the fact that certain series of lines are multiple.

Two of the simpler applications will serve to illustrate the accuracy of the theory and also the accuracy of modern spectroscopy. An atom of helium that has lost one electron should have the same structure as an atom of hydrogen, and should therefore give similar spectral series. This is found to be the case, but accurate measurements show that a

constant known as the Rydberg constant, which appears in the mathematical formula describing the series, is slightly different for the two, being $109677\ 70 \pm 04$ for hydrogen and $109722\ 14 \pm 04$ for helium. The difference between the two values arises from the motion of the nucleus, for the electron describes its orbit, not about the centre of the nucleus, but about the centre of mass of the two, from these two values, then, the ratio of the mass of the electron to the mass of the hydrogen atom can be calculated, and the result is found to agree with other determinations of this ratio within the limits of experimental accuracy. Again, in the case of the hydrogen atom or the singly ionized helium atom, if the mass of the electron is supposed constant, all elliptic orbits with the same major axis should correspond to the same amount of energy, but, if the variation of mass with velocity demanded by the theory of relativity is taken into account, the energy depends to a slight extent on the shape of the orbit as well as on its major axis. By making the relativity correction and applying quantum principles to the shape as well as the size of the orbits, Sommerfeld showed that the lines of certain series in the spectra of hydrogen and of ionized helium should have a "fine structure," each apparently single line really consisting of several lines very close together. This fine structure has been observed, and measured values of the separation of the lines are in satisfactory agreement with the calculated values.

For a final illustration of the possible scope of quantum theory and also of the untethered flights of modern physical theories, we may pass from the ultra-microscopic world of the atom to the world of stars and interstellar space. According to the theory of relativity, when a body gains or loses energy its mass increases or decreases by an amount equal to the energy change divided by the square of the velocity of light, and thus mass and energy appear to be mutually convertible—a view that is supported by astronomical measurements of the size and brightness of the fixed stars.

Now for the past thirty years various investigators have measured the electrical conductivity of gases that remains after all obvious causes have been allowed for, and experiments at different altitudes and under very various conditions of immediate surroundings suggest that this residual conductivity is due to radiations reaching the earth from outside. Measurement shows that such radiation must be much more penetrating and therefore of much higher frequency than any known radiation of terrestrial origin, for a screen of 70 cm of lead only reduces its effects to about one-half. Some observers claim that they have detected a greater intensity from the direction of the Milky Way, but there is no decisive evidence that the intensity varies with the direction, the conclusion is therefore that there exists a cosmic radiation originating in interstellar space of frequency much higher than that of the hardest γ rays.

Millikan and his colleagues, by sinking electroscopes to different depths in a snow-water mountain lake, measured the absorption of cosmic rays by water, and have analysed the results with a view to

determining the frequencies present. Millikan concludes that the cosmic ray spectrum consists of certain definite frequency bands, and in a recent paper he shows that these frequencies are consistent, in terms of relativity and quantum theory, with the view that cosmic radiation is due to a process of atom building taking place in interstellar space. He identifies three calculated frequencies with the formation from protons and electrons of helium, oxygen and silicon atoms, and finds that the relative intensities of cosmic rays of these frequencies correspond with the relative prevalence of these elements in meteorites.

The total annihilation of an atom of hydrogen by the proton and electron neutralising each other would give radiation of a frequency about four times as great as that of the hardest rays observed, Millikan concludes, therefore, that cosmic rays give no evidence of the disappearance of matter in interstellar space, and that this process is restricted to the interior of stars.

Thus, from observation of the rate of discharge of an electroscope under different conditions, it has been possible to build up a quantitative theory of atom building in interstellar space. Interpreting observed facts in terms of modern theory, it is possible, then, to formulate the following theory of cosmic processes—Protons and electrons, which exist in abundance in interstellar space, there combine to form atoms, and in so doing emit cosmic rays, these atoms aggregate under gravitation forming stars in the interior of which under conditions of very high temperature and pressure, matter is converted into energy which eventually passes to the outside of the star and is radiated. To complete the cycle, Millikan adds the suggestion, as yet unsupported by experimental fact, that in interstellar space radiation may be reconverted into protons and electrons. On the other hand, Jeans, who also has devoted much attention to cosmic physics, regards the second law of thermodynamics as universally valid, and so rules out the possibility of Millikan's last assumption.

Great as have been the achievements of quantum theory, it is impossible to regard it as yet adequate or mentally satisfying. It describes accurately the emission and absorption of radiation, but fails to describe transmission phenomena such as interference and diffraction. The rules for applying quantum theory to atomic structure at first sight seem mystic rather than scientific, the theory gives no account of the actual process of radiation, but merely represents it as the result of the passage, in some uncomprehended fashion, of an electron from one orbit to another, and there is the philosophic difficulty that the nature of the radiation depends only on the initial and final orbits, with the implication that the present functioning of the electron is decided by its future state.

Notwithstanding these difficulties and inadequacies, applications of quantum theory have been so successful that it seems certain that the theory, while not the whole truth, is at least partially true, the quantum of action appears to be indispensable in physical theory and there is

little doubt that it will be embodied in future theories which, for instance, will describe the process of radiation emission and adequately explain optical phenomena as statistical large-scale manifestations of discrete small-scale processes.

Numerous attempts have been made to devise schemes of quantum mechanics which give correct results when applied to atomic processes and yet avoid the difficulties of the ordinary quantum theory. Perhaps the most successful of these is wave mechanics, which is based on the analogy between wave motion and the motion of particles. In classical mechanics it can be shown that for a particle moving in a field of force, the path of the particle between any two points is such that the "action" is a minimum, and similarly in geometrical optics the path of a ray of light is such that the time taken is a minimum. With a suitable choice of symbols and conditions it is possible, therefore, to make a set of equations represent either rays of light or the motion of particles.

In accordance with the wave theory of light, rays of light must be replaced by wave motions, and the principles of geometrical optics can only be applied when we are considering large distances. For distances comparable with the wave length of light, quite different principles apply, as is shown by the phenomena of diffraction. Following this analogy, if the motion of a particle is represented by the equation of a wave motion, classical mechanics becomes a large scale description corresponding to geometrical optics, but, for atomic distances, the principles of classical mechanics no longer hold and the principles of wave motion must be substituted. In wave mechanics then, an atom is represented by a set of wave motion equations, and from these mathematical equations the facts of spectroscopy can be deduced.

This brief account, inadequate as it is, may serve to indicate the profound changes that have occurred in the world of physical theory. The perceptual materialistic world of classical theory has been replaced by a world of mathematical abstractions and at times we appear to have lost touch with "reality", space and time have no separate existence and matter has been reduced to sets of mathematical equations or, if preferred, to systems of wave motions.

But, after all, what is meant by reality in physical science? Questions concerning objective reality are outside the scope of experimental science for it is impossible to state that any particular concept, matter for instance, has a real existence, it can only be stated that certain concepts are consistent with our description of observed facts, so that, in the only sense in which the word has any meaning in physical science, reality is subjective and relative. A concept which is immediately necessary for our description of experimental facts, and with which we are familiar through constant use, we regard as representing something "real," and in the same way we regard a theoretical explanation as mentally satisfying if it is given in terms of concepts of a type that we recognise as familiar.

Kelvin objected to Maxwell's electro-magnetic theory of light as an attempt to explain *ignotum per ignotum*. To him, the electrical explanation was unsatisfying and only a consistent mechanical explanation would have been acceptable, but I think that, to a modern wireless engineer, alternating electric and magnetic forces in an electro-magnetic wave are as "real" as pressure variations of the air in a sound wave.

Our ideas necessarily become more seemingly abstract as our knowledge increases. The definitions of electric force and magnetic force given in elementary text-books appear to be quite reasonably simple and practical, but with increasing knowledge and as our ideas become more exact, we find that the "practical" aspect of the definitions is refined away till finally we come to the conclusion that the only accurate definitions of these quantities are given by the general equations of the electro-magnetic field.

New ideas are never appreciated at once, for it takes time for them to become familiar and therefore "real" to us. For instance, the ideas of relativity are now far more acceptable to everyday physicists than they were fifteen years ago, and, unless the theory of relativity has been replaced by some more satisfactory theory, in fifty years' time the four dimensional world of relativity will seem as "real" to everyday physicists as three dimensional space seemed to us a few years ago.

Absolute truth has no more meaning in physical science than has objective reality. We may draw comfort from an instinctive feeling that absolute truth exists as an elusive goal towards which we are slowly finding our way, but we can never hope to state a law or theory as absolute truth. In physical science the word "truth" can only be used to imply consistency, and the aim can only be towards a more comprehensive and accurately consistent description of phenomena. The scheme of Newtonian mechanics has been found to be inconsistent with observed facts, and examination has traced these inconsistencies to faulty fundamental assumptions. This scheme has been replaced by the relativistic scheme, which does not lead to these inconsistencies and is therefore regarded for the time being as "true", but the theory of relativity also makes fundamental assumptions, and should inconsistencies be discovered or a more satisfactory theory be devised, it will become "untrue" and be replaced.

In the development of satisfactory theories, partially true theories play a valuable part, for, to a limited degree of accuracy or within a limited range of phenomena, they systematise facts, and used deductively they suggest new methods of experimental attack, moreover, by selecting and combining ideas from several such partial and tentative theories it may be possible to develop a more comprehensively consistent and therefore more acceptable theory. The increased specialisation of scientific workers tends towards the use of such partially true theories. For instance, the Rutherford-Bohr atomic model has proved of the greatest value in spectroscopy, but that it is a very complicated model is obvious if we try to visualise, say, the atom of gold with its

seventy-nine electrons describing approximately elliptic orbits about the central nucleus. It cannot readily be used to explain the arrangement of atoms in molecules or to explain the molar physical and chemical properties of matter. On the other hand, the Lewis Langmuir type of static or *quasi* static atom model cannot be reconciled with any reasonable scheme of dynamics, and cannot satisfactorily explain radiation phenomena, but can explain the properties of the elements and so finds readier application in chemistry. There are then two groups of scientific workers using two distinct and contradictory models of atomic structure, but the members of each group know that both models are unsatisfactory and will sooner or later be replaced by a more satisfactory model which will include the good points of both.

At the present time any theory, however speculative, receives attention if it has scientific value, that is if it can be usefully applied to physical phenomena and be subjected directly or indirectly to the test of experiment.

The comparative orthodoxy of classical physics has given way to a healthy agnosticism characterised by greater tolerance and freedom of thought, increased scientific imagination, and a better realisation of the evolutionary nature of scientific concepts and theories.

The loss of the illusion of definiteness and reality has resulted in a wider and clearer vision, and, whether their period of usefulness prove short or long, the new ideas of relativity and quantum theory which have emerged from the confusion attending the partial collapse of classical theory mark a great advance in physical theory, an advance that profoundly influences all scientific and philosophic thought.

The Volatile Oil of Queensland Sandalwood (*Santalum lanceolatum*).

By T G H JONES, D Sc, A A C I and F B SMITH, B Sc, F I C

(Tabled at the Royal Society of Queensland, 25th March, 1929)

Santalum lanceolatum is one of the most notable representatives in the Queensland flora of the family Santalaceae, and it has for some years afforded a faintly perfumed wood which has constituted an article of export to Chinese markets, where it is stated to find use in the manufacture of joss-sticks and small fancy wooden articles¹. So far as is known to the authors the wood of this Queensland-grown sandalwood has not hitherto been distilled for essential oil, but Guildmeister and Hoffmann² record constants of a sandalwood oil from Thursday Island which probably would have been derived from this species. A R Penfold in a recent paper, "The Chemistry of Western Australian Sandalwood Oil,"³ describes an investigation commenced in 1925 of commercial and laboratory distilled oils including oils derived from *S. lanceolatum* of Western Australian origin, in which state the wood is distilled and the oil admixed with oil from *Eucarya spicata* (*Fusanus spicatus*) to constitute commercial Western Australian sandalwood oil.

The authors' examination (commenced in 1924) of oils derived from Queensland woods has been practically contemporaneous with that of Penfold and their results are considered sufficiently complete to warrant publication, particularly as they show a more considerable and variable range of optical rotation than recorded by that author, the high negative character of whose figures, we believe, may have been fortuitous. The oils described were, in the absence of efficient apparatus for conduct of steam distillation of the wood in bulk, derived by percolation of the wood shavings three times with low-boiling petroleum ether and distillation with glycerine *in vacuo* of the volatile oil from the extract, an adaptation of the method of Briggs⁴ for estimation of essential oil in sandalwood.

¹ We are informed by Mr C T White (Government Botanist) that though the tree has a wide distribution through North western Australia, the Northern Territory, Queensland, and New South Wales it is only those trees growing in the more tropical portions that possess a wood with a typical sandalwood odour, the wood of trees growing in Southern Queensland and New South Wales being entirely or almost entirely scentless. The wood of the Southern trees has in consequence no commercial value.

² Guildmeister and Hoffmann, "The Essential Oils," vol II, p 347

³ Journal Proc Roy Soc, N S W, vol LXI, 1928, 60-71

⁴ Jour Ind Eng Chem 1916, 420

The oils so obtained to the extent of about 4 per cent on the large scale¹ were clear, somewhat viscous, and bright yellow in colour. The odour in the cold was faint but was strongly aromatic on heating. In its comparative inodorousness in the cold it is thus contrasted with the oil of East Indian sandalwood (*Santalum album*) and the distinctly aromatic commercial West Australian oil derived principally from *Eucarya spicata*. The odour of the West Australian oil, which indeed closely resembles that of East Indian oil, is to be ascribed no doubt to the presence of santalol, which Penfold considers from application of the santalenic acid test to be present to the extent of 40 to 45 per cent.

On the other hand oxidation of the oil of *Santalum lanceolatum* with potassium permanganate in the manner prescribed by Chapman and Penfold (*loc. cit.*) failed, in the hands of the authors, to yield a substance identifiable with santalenic acid, and for this reason it is believed that santalol is not a constituent of the volatile oil of *Santalum lanceolatum*.

It will be observed, from consideration of the constants given in Table I, that there is considerable variation in the constants of the oils derived from trees in various parts of Queensland. Although in the main the oil derived from coastal districts (such as that of the bulk of our wood which came from Cooktown) resembles that of the West Australian *Santalum lanceolatum* oil in the high negative optical rotation, nevertheless oil derived from trees at Hughenden and Atherton shows a much smaller negative rotation.

In the case of a small sample (6 lb)² obtained from Hughenden in 1928 a positive rotation was recorded for the oil, but larger supplies forthcoming at a later date³ from this same area failed to reproduce the positive rotation, and we were thus unable to complete the examination of this unique variety of oil with its positive rotation. The variation in optical rotation, accompanied by less noticeable variations in density, is no doubt due to variation in the proportions and rotations of the optically active alcohols and terpenes which are the constituents of the oils.

As most of our oil was from wood received from Cooktown and possessed of high negative rotation, our investigation has chiefly centred around this oil and the main results are to be ascribed to it.

The principal constituents of all the oils are alcohols which form 80 to 90 per cent, together with smaller quantities of sesquiterpene. The alcohol consists of a mixture of two and possibly three isomeric sesquiterpene alcohols, the principal one possessing a specific rotation of approximately -63° . That this is also the principal constituent of oil

¹ Small scale ether extractions gave a yield of 5 per cent. this oil slowly deposited a small amount of crystalline material.

² Sample 5.

³ Sample 6. The density of the alcohols from this sample was, however, higher than from the others except sample 5.

of West Australian origin is indicated by Penfold's description of a fraction therefrom with specific rotation -70.4 and our own examination of a sample of this oil obtained by courtesy of the Forestry Department, West Australia.

A second alcohol was obtained with notably high density (0.908) and positive specific rotation ($+26$), and there also appeared to be further indication of a third alcoholic constituent with somewhat higher density than the main alcohol previously noted.

It is doubtful if these alcohols were obtained in a state of high purity on account of the difficulty of separating them completely by fractional distillation *in vacuo*, the third-mentioned was apparently present only in small amount, and its even partial separation appeared to be inhibited by gradual resinification of the higher fractions. Penfold separated a similar dextro-rotatory alcohol to the above from the oil of *Eucalypta spicata* by differential combination with phthalic anhydride. We were, however, unable to effect any clean separation of the dextro- and levo-rotatory alcohols of *Santalum lanceolatum* by this method, although a rough separation is undoubtedly obtained. The authors consider that the constants recorded for the levo-rotatory alcohol by Penfold were no doubt derived from a purer sample than they were able to obtain even after prolonged fractional distillation, due in all probability to the almost complete absence of the dextro-rotatory alcohol in the sample examined by him, and our examinations of oils from different localities in Queensland seems to indicate that the percentage of this dextro-rotatory constituent is variable, falling to a minimum in highly negative oils.

EXPERIMENTAL

TABLE I

CONSTANTS OF SANDALWOOD OILS (*SANTALUM LANCEOLATUM*)

Locality	Density d_{15}	Specific rotation $[\alpha]_D$	Refractive Index n_D^{20}	Acetyl Value	% of Alcohols present
1 Cooktown 1926	9554	-47.1	1.5062	191.9	88
2 Cooktown 1927	9522	-42	1.5068	186	86
3 Hughenden 1927	9592	-8	1.5082	187	86
4 Atherton 1927	9612	17	1.5068	180	82
5 Hughenden 1928	9766	$+12$	1.5100	184	85
6 Hughenden 1928	9537	-30	1.5050	186	86
7 West Australia (supplied by Forestry Department)	9607	-42.6	1.5004	161	73
8 West Australia (distilled by Penfold)	9446	-61	1.5055	193.4	89
9 Atherton 1925	9546	-30	1.5050	184	85

Sample 9 was obtained by steam distillation of shavings, and the oil was found to differ very little from the other petrol extracted oils.

Fractional distillation of Sandalwood oil

Five hundred cubic centimetres of oil [a] D—47.1 were fractionally distilled at 5 mm pressure. The data of fractions obtained in one such distillation are recorded in Table II.

TABLE II

Fraction	Boiling Point	d ₄ 4	[α] _D	n _D ²⁰
20 cc	0–124°C	0.900	–33	1.4930
36 cc	124–138°C	0.9395	–38	1.5002
146 cc	138–141°C	0.9522	–45	1.5038
148 cc	141–146°C	0.9530	–53	1.5054
150 cc	146–152°C	0.9510	–58	1.5055

Separation of alcohols by treatment with phthalic anhydride

For separation of the alcohols recourse was had to the standard phthalation process. In a typical experiment 100 grammes of oil were heated with an equal bulk of phthalic anhydride and 75 cc benzene under reflux. The bulk of the phthalation was effected in one hour but was continued for two hours. Alcohols still uncombined with phthalic anhydride were subsequently further treated at 140 deg C in the absence of benzene. The total acid phthalates were decomposed by hydrolysis with alcoholic sodium hydroxide, and the recovered alcohols distilled completely for purposes of clarification. The constants of the alcohols recovered from various samples of oil are recorded in Table III.

TABLE III
ALCOHOLS SEPARATED FROM SANDALWOOD OILS

Sample	d ₁₅ 5	[α] _D	n _D ²⁰
1	0.849	–51.5	1.5080
2	0.866	–44	1.5082
3	0.900	–9	1.5100
4	0.863	–19	1.5104
5	0.884	–17	1.5110
6	0.898	–35	1.5104
7	0.887	–47	1.5010
8	0.974	70.4*	1.5074
9	0.878	–33.4	1.5010

* The figures quoted for sample 8 were derived from Penfold's paper (loc. cit.)

The alcohols from sample 5 were unique in possessing a positive rotation and unusually high density, but only a small sample of this oil was available. It was not possible to examine it closely, but it would seem that the alcohol of positive rotation reached a much higher proportion in this oil than in the others, and indeed became the dominant constituent.

Fractional distillation of the alcohols

In order to separate the alcohols from one another, prolonged fractionation under 5 mm pressure was resorted to. The figures quoted in Table IV refer to the fractions obtained in the first fractionation of the alcohols (1,200 cc) obtained from sample 2.

TABLE IV

—	Fraction	d_{15}^4	$[\alpha]_D$	n_D^{20}	B.P. Range
1	235 cc	9593	— 36	1.5086	} 140°C to 150°C
2	250 cc	9544	— 41	1.5084	
3	260 cc	9536	— 45	1.5080	
4	250 cc	9522	— 50	1.5080	
5	145 cc	9560	— 55	1.5076	

It will be seen from this table that the presence of three alcohols is indicated, but on further fractionation it was found that one of these was present to a much greater extent than the others.

Ultimately after prolonged fractionation two alcohols were separated in a state of approximate purity, for which the following constants were recorded —

Alcohol No 1

d_{15}^4 9908 $[\alpha]_D + 28$ n_D^{20} 1.5127 b.p. 142°C 5 mm pressure

Molecular Composition— $C_{15}H_{24}O$

The percentage of this alcohol in the mixed alcohols could scarcely exceed 10 per cent and was probably less than this.

Alcohol No 2

d_{15}^4 9510 $[\alpha]_D - 63$ n_D^{20} 1.5062 b.p. 148°C 5 mm

Molecular Composition— $C_{15}H_{24}O$

This alcohol—possibly a mixture of closely similar isomers—is the dominant constituent of the oil and constitutes at least 80 per cent of the mixed alcohols, being responsible for the usual pronounced *lævo*-rotation of the oils.

The constants quoted by Penfold for this alcohol are—

d_{15}^4 9474 $[\alpha]_D - 70.4$ b.p. 163°–165° 5 mm

which resemble those given above in all except the boiling point which is 15 deg C higher. We were unable to confirm this high boiling point.

Sesquiterpene constituents of oil

Repeated fractionation of the original oils led to the isolation of a fraction with a somewhat lower boiling point than the alcohols. As preliminary examination indicated the presence of sesquiterpene, the

fraction was repeatedly distilled over metallic sodium and finally collected as a colourless liquid with the following constants —

d_{15}^4 8954

$[\alpha]_D^{20}$ —30

n_D^{20} 1.4900

Molecular composition $C_{15}H_{22}$

The sesquiterpene did not give the usual colour reaction with bromine vapour and acetic acid

The investigation of the constitution of this sesquiterpene and the alcohols described is being continued

The authors wish to express their thanks to the Forestry Board, Queensland, for their usual courteous assistance in obtaining samples of sandalwood from their various forest stations, to Mr C T White, Government Botanist, for verification of authenticity of specimens, and to the Chemical Society Research Fund for a grant to one of us (T G H J) which defrayed part of the cost of this investigation

The Relative Value of Larval Destructors and the Part they play in Mosquito Control in Queensland.*

By RONALD HANLYN HARRIS, D Sc

(Read before the Royal Society of Queensland, 27th May, 1929)

The idea of controlling mosquitoes by means of their natural enemies sounds so exceedingly attractive that many are tempted to place an unwarranted amount of confidence in what has rarely proved of any great value. That natural enemies under natural conditions, are capable of taking a large toll of mosquito life cannot be denied, and for that reason alone they are worthy of considerable encouragement. In a country like ours, subjected to severe drought conditions, waters change so rapidly, topographically as well as in physical and chemical characteristics, that it would be very unwise to place false faith in what we know only to be effective under the most ideal of conditions. Nature erects many natural barriers against the undue preponderance of most larval destructors and against fish in particular. Yet the question of biological control is vastly important, and it is necessary that we should have a thorough knowledge of those natural enemies which we believe to exist and which might be of some value on the one hand in order to apportion them as opportunity affords, and on the other to prevent their ruthless destruction due to ignorance.

The presence of numerous mosquitoes in any given water may be taken as evidence (1) That the water is in itself suitable for their development, (2) That the food which that particular type of mosquito larva requires is available.

On the other hand the absence of mosquito larvae in certain waters may be due to a great variety of causes as yet but very imperfectly understood. The absence of suitable food is possibly the most important, and by far the most far-reaching, factor influencing selection.

Where there is a total absence of food due to the presence of larger aquatic animals, mosquito larvae do not occur. Sometimes there is an abundance of organic matter, together with certain poisonous excretory material, which is responsible for a low oxygen content of the water, and these factors, amongst others, doubtless have a direct bearing upon the attractiveness or repulsiveness of the water in question, sometimes to such an extent that the smaller varieties of larval destructors become scarce whilst fish would probably, under such circumstances, not live at all. Unless suitable conditions exist for larval destructors to maintain themselves, there can be no control of mosquitoes along these lines.

* From the Entomological Section of the Department of Health, Brisbane City Council.

TYPES OF WATERS

The types of waters selected by mosquitoes require detailed study. In earlier campaigns it was a common practice to oil, to drain, or to fill every potential breeding place irrespective of whether it was breeding mosquitoes or not, and very little attention was given to the type of water concerned. This rather drastic method proved fruitful of good results, but it is recognised to have been an exceedingly expensive method of control, for it is now considered quite unnecessary to interfere with waters which are not in any way a mosquito menace. Modern methods demand that the examination of the water be made in detail, and that its whole natural surroundings and contents be taken into consideration in order to ascertain the factors involved in rendering such waters attractive or unpalatable as the case may be. Such anti-mosquito work involves considerable entomological study, specially with regard to the bionomics of each different type of mosquito encountered. It is extremely difficult to make this phase of the question clear to the lay mind, but as so very frequently the layman has to find the necessary sinews of war it is highly desirable that the problem from this standpoint should be understood by him.

THE CHARACEÆ AS POSSIBLE LARVICIDES

It has been thought by some that the presence of certain Characeæ in natural waterholes is sufficient to prevent mosquito breeding in waters in which they occur, but our experience here in Brisbane totally disproves any such possibility. These algae are so extremely plentiful in and around Brisbane during the summer months, that sometimes waterholes with Characeæ are far more common than waterholes without them, and opportunities for studying them in connection with mosquito breeding are never wanting. A minute examination of a chain of waterholes forming an arm of the Enoggera Creek was recently made in order to ascertain what aquatic life was likely to exist in and amongst the various species of Characeæ, which occur in such large quantities as to completely cover the floor of the waterholes.

The insect fauna of one waterhole is very much the same as another. Most of the predatory insects mentioned in this paper occur.

Culex annulirostris is always plentiful on these occasions and so is *Anopheles annulipes*. Both these mosquitoes shelter in and among the *Nitella*, and without some such shelter it is questionable whether these mosquitoes could exist at all in the face of all the various larval destructors which exist in one such waterhole. When once disturbed the larvæ of these mosquitoes can be located without any difficulty, they usually occur more frequently than not in association.

In view of these facts it is indeed strange that *Nitella phaulotekis*, for one, should have been considered an effective larval destructor, for our observations go to show that, instead of destroying these sylvan mosquito larvæ, the plant tends to afford them necessary protection from their natural enemies. There are, of course, other sylvan mosquitoes which select these waters from time to time, at different periods of the year.

CANNIBALISTIC MOSQUITOES

We have in Queensland several mosquitoes that are cannibalistic in the larval stage, and with their highly developed and formidable mandibles are capable of wonderful execution. Of these *Lutzia halifaxi* Theo, in polluted water, *Aedes (O) vittiger* Skuse, in fresh water, and *Mucidus alternans* Westwood, in salt water, stand out in importance.

With regard to *Lutzia halifaxi*, it is a pity that it is not possible to utilise this species and turn its cannibalistic tendencies to a useful purpose in anti-mosquito work. Though this formidable insect breeds in the main in polluted water it does not bite under Australian conditions and is, therefore, quite harmless, but it has a distinctly seasonal occurrence in Brisbane and would therefore be only of small practical value.

Megarhinus speciosus Skuse is also cannibalistic in the larval state. This species is, however, for the greater part a breeder in tree cavities, and would therefore as such be of very little use biologically. It is not a plentiful mosquito, but there is no knowing what wonderful use might be made of this species under suitable conditions, and it is highly desirable that the question should be studied from this standpoint.

Wigglesworth²² has a note in "Nature" with regard to *Megarhinus brevipalpis*, and suggests a means by which predaceous mosquitoes such as this might be introduced into distant countries with a minimum loss of life.

TADPOLES AND MOSQUITO LARVÆ

Mosquitoes have many enemies other than fish which take considerable toll of the many different species, and to which some reference here is justified. It is, of course, somewhat difficult to substantiate all at once the numerous references to larval destructors which, in many cases, are based on popular ideas or mere hearsay, though possibly founded upon a truthful observance in the first place. There is for instance the question of frogs and frog larvæ. The author has seen on more than one occasion adult frogs snap at adult mosquitoes and devour them, but has never been successful in discovering whether tadpoles really devoured mosquito larvæ or not. Tadpoles are evidently vegetable feeders. There is no direct evidence in Queensland to justify the idea that they devour mosquito larvæ. Sometimes the absence of larvæ in waters frequented by frogs and their progeny seems fairly conclusive, and yet this is not the case in waterholes in which *Nitella* affords protection, for in such, sylvan mosquito larvæ may occur side by side with tadpoles in the same water. It is a common occurrence to find frogs in tree cavities resting with their bodies half in the water, but the numbers of larvæ of *Aedes notoscriptus* in such water do not seem to be any the less. Pruthi, writing from India, says that the tadpoles of the common frog *Rana tigrina* seem to be very fond of larvæ. He states that one full-grown tadpole can consume from fifteen to twenty-one larvæ in a period of twenty-four hours, but unfortunately I have no evidence of this sort to offer. On the contrary, the presence of

numbers of tadpoles in water in which mosquito larvæ are known to occur is inexplicable unless the habit of eating mosquito larvæ is restricted to certain species only

PREDATORY INSECTS

Most predatory aquatic insects may be broadly classed as larval destructors

AQUATIC HEMIPTERA ARE MOSQUITO DESTROYERS—Waters in which they occur are usually of a more persistent character. Mosquito larvæ as a rule are not plentiful where these occur, and yet, when the water is full of a fine vegetable growth such as is provided by various species of Charophytes, aquatic bugs act only as a check, not as a control. In the Brisbane district our Characeæ harbour and support a very large and varied number of small insect forms including mosquito larvæ, both Culicines and Anophelines. In such we frequently find these aquatic predatory insects in large numbers side by side with mosquito larvæ, a condition only possible when a considerable amount of food is available. For the rest *Nitella* proves such an effective harbour of refuge that larvæ of sylvan mosquitoes apparently hatch often without any interference from their natural enemies.

SUPR-FAMILY GERROIDEA—This contains two families of water striders, the Gerridae or Pond Skaters, and the Hydrometridæ known as Slender Water Striders. These are easily recognised as insects which slide along the surface film of the water in a series of jerks. Their interest lies principally in their diving habits for food, the eggs are laid on water weeds, *Vitella* being frequently selected for this purpose. There seems to be some doubt in the minds of certain entomologists as to the accuracy of the statement that these insects are known to be larval destructors, but the author of this paper has been able to secure definite evidence that these Hemiptera do eat mosquito larvæ when other suitable food does not seem to be available, and in this connection it is interesting to note that Pruthi¹ in India has made similar observations.

SUPR-FAMILY NOTONECTOIDEA—There are four important families belonging to this group, containing insects which are all of them effective larval destructors, as we can testify from personal observation.

FAMILY NEPIDÆ—WATER SCORPIONS—These are fairly common insects, and various species occur in Brisbane, of which the following is only one—*Laccotrephes tristis* Stal. Members of the Nepidæ kill mosquito larvæ by piercing the skin with their rather delicate proboscis and sucking out the juicy contents. These rather sluggish creatures find no difficulty in procuring Anopheline larvæ for their prey.

FAMILY NAUCORIDÆ—WATER BUGS—These are often very plentiful, and in many respects resemble *Notonecta* in their habits. I have personally noted species of *Naucoris* darting at resting mosquito larvæ (sylvan), and dragging them under the surface of the water. They are also fond of Chironomid larvæ and pupæ.

FAMILY BELOSTOMATIDÆ—The Giant Water Bug *Lathocerus indicus*, known locally as the "Fish Killer," is a member of this family. That certain members of this family devour mosquito larvæ is borne out by Pruthi. The author has no personal knowledge with regard to the ability of this giant bug to devour mosquito larvæ, and it is more than likely that this insect is far too big to bother about such small fry. I can only point out that Pruthi records his having seen this bug in his experimental jars devour four larvæ during a period of twenty-four hours.

FAMILY NOTONECTIDÆ—BACK SWIMMERS—These predaceous insects are quite common in our area and are very effective mosquito destroyers, it is a matter of common knowledge that they are carnivorous, and are very fond of a mosquito diet. The back of *Notonecta* is keeled, enabling it to swim on its back. Their eggs are laid on water plants.

SUPER-FAMILY CORIXOIDEA—This possesses a single family—the Corixidæ—also called Water Boatmen, but differing from *Notonecta* in many important particulars. *Corixa* swims on its back, but is not keeled, the back is flat, they devour one another if food is scarce, and lay their eggs on water weeds. Certain algæ, probably of the *Nitella* type, provide them at times with food, for they occur very plentifully in such waters. Corixidæ kept in confinement devour mosquito larvæ with relish.

AQUATIC COLEOPTERA ARE MOSQUITO DESTROYERS—It is probably true that most Coleopterous larvæ are larval destructors of importance.

SUPER-FAMILY CARABOIDEA—Water beetles of the family Dytiscidæ are very numerous in our area. They can easily be detected, because both the larvæ and the imagines have to take air by rising to the surface of the water. *Cybister gayndahensis* MacL is a common Brisbane species.

SUPER-FAMILY GYRINOIDEA—To this belong the Gyrinidæ or Whirligig Beetles. These frequent fresh water, and make use of water weeds for laying their long, slender eggs. The larvæ of this family are extremely active and voracious, they possess powerful biting mandibles, which are capable of making short work of mosquito larvæ, especially of Anophelines, which live in the upper layers of the water. The eggs are laid in summer on the stems of aquatic plants, *Nitella* being frequently selected for this purpose.

SUPER-FAMILY HYDROPHILOIDEA—The adult members of the family Hydrophilidæ are vegetarians, but the larvæ are predatory. This family contains many fine types quite common in our local waterholes. The larvæ are particularly vicious feeders, if one can judge by their methods of attacking their prey.

ORDER HYMENOPTERA—There is a small "Policeman Fly," known as *Sericoophorus relucens* Smith, common throughout the Brisbane area, Queensland, and New South Wales generally, which can frequently be seen catching mosquitoes on the wing, and carrying them to its nest, it is not an uncommon thing to catch this Hymenopteron in the act. It belongs to the family of the Nyssonidæ (Hamlyn-Harris,¹²) I had several such in my collection until the mites got them.

ORDER DIPTERA — This order doubtless possesses various species of flies which also catch mosquitoes on the wing. One of these "robber" flies common along the coast and in Central Queensland is worthy of mention, namely, *Itomosis culicivora* White. Of the smaller robber flies several appear to be useful in this direction, and can now and then be taken with mosquitoes in their jaws. Dr T. L. Bancroft, of Eidsvold, has made similar observations.

AUSTRALIAN ODONATA — In a paper of this sort it is quite sufficient to state that this order includes all those insects commonly known as Dragon Flies, which may be rightly described as the tyrants of the insect world. There is no doubt that they are amongst the most effective larval destructors we have, for not only do the adult dragon flies catch mosquitoes on the wing, but all the larval forms are known to destroy other insect larvæ which dwell in water weeds, which form a very profitable hunting-ground for all the members of this sub-order. Their persistent perseverance, which enables them to clear waterholes of all aquatic life, is truly wonderful. They are also very destructive to all small fish. In the laboratory they have been observed to destroy almost all small forms of aquatic life.

LARVAL DESTRUCTORS IN THE RICE-FIELDS OF NEW SOUTH WALES — A recent visit to the Murrumbidgee Irrigation Area of New South Wales has enabled me to witness an immense number of larval destructors actually at work in the field. One cannot help being very much impressed with the extremely useful work that these creatures are doing in keeping a check on mosquitoes. Where mosquitoes did exist in their presence, the former were present only in very small numbers. Natural enemies in these waters consist for the greater part of larval forms of Hemiptera, Coleoptera, and Odonata. These on account of their great numbers constitute a very valuable check on mosquitoes in the rice-fields during the early stages of the rice's growth. Towards the end of the rice season, there is evidence, however, that mosquitoes become too plentiful for the larval destructors to cope with them.

HYDRA AS A CHECK UPON MOSQUITO LARVÆ

Where these occur they are most effective mosquito destroyers. It has been the author's good fortune to feed *Hydra* on many occasions. The *Hydra* anchored against the side of the vessel catch the larvæ in their tentacles as they wriggle in the water, paralyse them almost instantaneously, and never relinquish their hold until the larvæ are dead or useless as food.

VORTICELLA

Colonies of *Vorticella* are sometimes so plentiful that it is thought they exercise some check upon mosquito larvæ. In certain types of permanent pools they sometimes occur in large numbers. These pools are selected by Anophelines on account of their plentiful food supply. Such Anopheline larvæ examined have at times been so heavily infested that they have died before pupation. In Brisbane, *Anopheles annulipes*

is the one usually attacked. The large numbers of *Vorticella* found more especially attached to the mouth organs and the breathing-tubes must, one would think, occasion the larvæ some considerable discomfort.

FRESH-WATER SNAILS

Some of these grow very fond of mosquito eggs. Detailed observations with regard to the habits of snails as a whole have not been possible, but the author has observed *Bullinus pectorosus* Comad feeding on eggs and egg-rafts on many occasions. If present in sufficient quantities, these snails will keep the surface of the water free of eggs all the time. The mysterious disappearance of eggs or their apparent inability to hatch has often been explained later by the habits of this small snail.

OTHER ENEMIES

In addition to the above there are also birds, bats, and lizards, possibly mites, to say nothing of possible fungoid diseases, which may possibly be responsible for considerable mosquito reduction in nature, but of the results of which we are comparatively ignorant.

It is rather a curious thing that *Teniorhynchus* (*Mansonioides*) *uniformis* Theo should be so frequently taken in Brisbane with mites attached to the lower end of the thorax. These mites are Hydrachnid larvæ, which apparently attach themselves to the mosquito before it leaves the water. Why these should select just one particular type of mosquito is curious. Out of every ten specimens taken, usually after heavy rains (1927-1928), more than half were parasitised, but I have no evidence to show that they are in any way inconvenienced thereby ('Consult Balfour,' Boyd, 'Dye' 11).

LARVIVOROUS FISH

It is only of comparatively recent date that mosquito control by the means of larvivorous fish has been taken seriously. It has of course been known for a very long time that mosquitoes form a regular part of the diet of certain fish, but, although some attention has been paid to fish suitable for mosquito destruction in this State, no attempt, as far as I know, has been made until quite recently, to give practical application to the knowledge gained.

Cooling's preliminary observations published in the Annual Report of the Commissioner of Public Health for Queensland, 1913, are of great value and undoubtedly form the basis of this work in Queensland. Since then no one seems to have done any independent work.

All our creeks and watercourses contain fish during the greater part of the year, and these small fish, of whatever species they are, effectively keep these streams clear of mosquito larvæ, but while there can be no doubt that larvæ eating fish are of practical value under ordinary normal conditions in the field, they can be made of greater practical value under artificial conditions.

Fish control is, after all, confined to somewhat narrow limits, but within these limits it must be recognised that it can be made very

valuable, and at times has been found to be the only practical method of control, and it is in view of these facts that their use on a larger scale is hereby strongly recommended. Under natural conditions fish are very frequently practically useless, owing to the fact that the fish cannot get at the larvæ which are protected by various kinds of aquatic and other vegetation. On the other hand some sort of proper protection is necessary if the smaller fish are to be safeguarded from the attacks of larger fish, that is why shallow water is a protection in itself, forming a natural sanctuary within its shallows.

Larvivorous fish are of special value in ornamental ponds and lakes in which the vegetation is under control, and it is a thousand pities that we have so few of these in Queensland. There seems a perfect mania for the destruction of ponds which, with very little trouble, could be converted into useful ornamental waters stocked with a fine assortment of suitable fish, as is the case in all the older countries of the world. Unfortunately, Queensland is very dry at times, and large sheets of water containing fish are apt to dry up.

FAMILY RETROPINNIDÆ—*Retropinna semoni* Weber (Fig 1). This smelt is a beautiful little fish plentiful at times in the Enoggera, Ithaca, and Moggill Creeks, where we have taken it in small comparatively shallow pools which are only connected with the waters of the main channel at flood-time. These fish, like *Craterocephalus fluviatilis*, which they resemble, are voracious devourers of mosquito larvæ, and where they exist are of even greater value than has hitherto been thought possible. The smelt is very rapid in its movements, and being capable of detecting adult mosquitoes on the water surface at some distance is particularly efficient. Its value in mosquito control consists in its love of roaming over large areas of waters if available, in its exceedingly rapid movements as a surface feeder, and its extreme fondness for mosquito larvæ.

FAMILY ATHELEINIDÆ—*Craterocephalus fluviatilis* McCulloch—The Freshwater Hardyhead (Fig 2).

Natural Habitat—This fish occurs abundantly in freshwater streams and deep permanent waterholes. It is more abundant in the western rivers of New South Wales than in Queensland. Adults vary in size from 2 to 4 inches, and can be taken in the shallows along the banks often in very large numbers.

Natural Habits—Its egg is an adhesive demersal one and relatively large. The spawning season is during the warmer months—a cold season retards development but its best spawning time is during October and November. The fish make no "nest" or "redd" as does the trout, but deposits its eggs in crevices between the rocks and on the clean rocky bed of the river in a shallow narrow stream, perhaps not more than 12 inches deep.

The Hardyhead is shy and very rapid in its movements, and unless it occurs in large shoals, as is frequently the case, it is not at all easy to catch. It is a true mosquito destroying fish and should be encouraged in every possible way. It is entirely suitable for use in a trout hatchery.

It occurs in numbers in the Reservoir at Enoggera McCulloch has described a species from the Burdekin River which he named (*C. maculatus*, but it is, I understand, a synonym

Its Use in the Rice-fields of New South Wales—This fish cannot be too highly recommended for mosquito work in the Murrumbidgee Irrigation Area of New South Wales. The actual difficulty might be to procure it in sufficiently large numbers to be effective, but as this fish lends itself particularly to stripping there should be no reason why large quantities of this Hardyhead should not be procurable. The breeding of these in hatcheries, if necessary, should not be either a difficult or an expensive item, and if large numbers could be introduced into the waters of the main canal, after leaving Beemba weir, they would gradually work their way through the irrigation area even as other fish are known to do at present. It is not an uncommon thing to see small fish swimming about in the rice-fields, but these are of no known value in mosquito control. It is a suggestion well worthy of the notice of the authorities concerned.

FAMILY MELANOTFINIDÆ—*Pseudomugil signifer* Kner—The Queensland Blue-eye (Fig 3)

Natural Habitat—Adults of this species which attain to 1½ or 2 inches in length are found very abundantly in all waters subject to tidal influence, but as it can adapt itself without any inconvenience to fresh water it is found also along the coastline in the rivers of Southern Queensland. The Blue-eye does not frequent polluted waters except temporarily in order to snatch such organic morsels of food as the water may yield at the moment. City drains provided with household refuse which empty into tidal channels attract sometimes large shoals of these fish. Fig 4 represents such a city drain served by tidal waters, it shows a tendency to become polluted, causing Blue eyes to feed here for the greater part of the year.

Natural Habits—This small fish is an exceptionally efficient mosquito destroyer. On account of its size it is able to work its way to the very edges of the water, a habit which it has in common with tropical larvivorous fish. It is mainly a surface feeder and does wonderful work in controlling mosquitoes in all tidal waters.

MELANOTFINIA NIGRANS Richardson—The Crimson-spotted Sunfish (Fig 5)

Natural Habitat—This beautiful fish occurs under natural conditions in clear fresh water, avoiding dirty water except on rare occasions. The adult forms reach a length of about 2½ to 3 inches and occur in all fresh-water creeks and large waterholes periodically served by flood waters. Sunfish are sometimes trapped in waters unsuited to their natural habits, and occasionally they are to be found in waters supplied with local drainage in which they are only capable of living for a short time. A large batch recently found in a polluted waterhole yielded specimens all of which ultimately died through a heavy infestation of *Saprolegnia*, a fungus to which this fish is at times rather prone, particularly under such adverse conditions.

Natural Habits.—This fish does well in aquaria and after a time loses its shyness. It is undoubtedly one of the best of our larval destructors, and will feed not only on larvæ and pupæ but also on eggs and especially adults. It is by no means cannibalistic, for it seldom if ever will eat small fish either of its own or any other species. It will live quite peaceably side by side with Barbados Millions without making any attempt to eat the young *Lebistes*. This characteristic is of such tremendous advantage that it has been responsible for the selection of this fish for use in the Brisbane City Council's hatchery in South Brisbane (Fig 6).

Fig 7 shows a typical water frequented by these fish. It is a portion of Enoggera Creek on the Waterworks road. Here there occurs a copious growth of *Hydrilla verticillata* in which the majority of our Queensland larvivorous fish find harbourage and food.

Fig 8 is a reproduction of a portion of the same creek separated in dry weather from the main stream, and used by the Queensland Spotted Sunfish for breeding purposes. This pool during the month of January 1928 was full of various aquatic plants, especially *Hydrilla* and *Nitella*, and hundreds of young Sunfish disported themselves in this sheltered spot. Such breeding places are, of course, by no means of a permanent nature but are dependent upon weather conditions. By the time the waters rise and flood such natural refuges, the fish are generally old enough to look after themselves. The eggs are probably pelagic, which would account for their being laid in safely protected waterholes.

FAMILY AMBASSIDÆ—This family contains a number of fish probably extremely useful in mosquito control, in fact, it is not at all unlikely that every member of the genus is larvivorous. Only one, namely *Priopsis olivaceous*, has been definitely described as a larval destructor, but it is very likely that *Ambassia agassizi* Steindachner (South-east Queensland, &c.), recorded from inland creeks, may be equally effective. The Yellow Perchlet, *Priopsis marianus* Gunther, recorded from the Mary River and Moreton Bay, should be capable of doing good work in salt or brackish water. The whole genus requires closer investigation from this standpoint.

PRIOPSIS OLIVACEOUS Ogilby —The Green Perchlet (Fig 9)

Natural Habitat—This fish prefers clean deep water, where large schools are generally found. Small batches occur in shallow waters in company with other types of fish. The Perchlet does not favour polluted though it is sometimes found in muddy waters.

Natural Habits—Though this fish is extremely voracious, it has from the mosquito standpoint the fault of being cannibalistic. When hungry the Perchlet will devour any fish small enough that comes within its reach. In captivity it is cannibalistic, at all times, provided the opportunity is given. It lays floating eggs among vegetation and is on the whole rather shy. We have never been able to get it to breed in captivity.

FAMILY ELLOTRIDÆ—The three Gudgeons here referred to all belong to the same family and are not dissimilar in their habits. As the fish of the larger species reach maturity they tend to develop a cannibalistic tendency. They prefer the coarser food available at the bottom of a pool or creek to the mosquito larvæ which frequent the surface layers of the water, and will devour the smaller fish of their own as well as those of other species when procurable. Instances are on record of the Carp and Trout Gudgeons completely wiping out the smaller Fire-tailed Gudgeons, and observations go to show that the latter fish avoid unnecessary proximity to the former as a matter of expediency. These gudgeons cannot be classed as truly larvivorous though they are larva-eating fish which is a different thing, however. It is a question whether they exercise any appreciable mosquito control except perhaps where they occur in such overwhelming numbers that mosquito larvæ must necessarily form a part of their daily diet, but as larva-eating fish they have their value.

MOGURNA (MOGURNA) ADSPERSUS Castelnau —The Trout Gudgeon (Fig 10)

Natural Habitat—The Gudgeons are all bottom feeders, and occur at times together in large numbers, but at other times each different species is found by itself. The distribution of the Trout Gudgeon, according to Cooling, is said to be from the Fitzroy River, in the north, to the Upper Shoalhaven district in the south. It occurs in all waters frequented by other larvivorous fish, with the exception perhaps of the Blue-eyes, but is less noticeable, especially during the cooler weather, when in common with other Gudgeons it hides itself in the mud or vegetable matter at the bottom of the water until the spring calls it forth to breed.

CARASSIOPS COMPRESSUS Kieft —The Carp Gudgeon (Fig 11)

Natural Habits—The remarks made with regard to the Trout Gudgeon also apply to this fish, which does not, however, consort with them for choice. It does not grow as big as the Trout Gudgeon, and is on the whole less fierce in its methods of attack.

CARASSIOPS GALII Ogilby —The Fire-tailed Gudgeon (Fig 12)

Natural Habits—This small gudgeon is the most useful of the three, but though very common in the whole eastern portion of Queensland, does not occur in such large numbers as the other two gudgeons do. It is to be found in fresh-water creeks and in any backwash, as well as in large waterholes usually of a shallow nature. Being of a small size (adults rarely exceed 2 inches), it is preyed upon by the larger specimens of fish, and consequently it likes to isolate itself in large shoals in out-of-the-way potholes of watercourses, where in fairly deep water provided with plenty of aquatic weeds it disports itself and breeds.

CARASSIOPS KLUNZINGERI Ogilby—This fish is very closely allied to the Carp Gudgeon, and is reported from the Burnett River district as a valuable mosquito fish (Dr T. L. Bancroft). We have no knowledge of its occurrence in the Brisbane area.

FAMILY THERAPONIDÆ—*Therapon unicolor* Gunther is an excellent mosquito fish (T. L. Bancroft) Unfortunately, it has not as yet been recorded from the Brisbane district, but it seems fairly plentiful north of the Mary River

OTHER FISH SUITABLE FOR SALT-WATER CONTROL

BUTIS AMBOIENSIS Bleeker—Closely related to these Gudgeons there is a salt-water species occurring in the Brisbane and other tidal rivers of Southern Queensland known as *Butis amboiensis*, which we have reason to believe is also a larval destructor of some importance. The total absence of mosquito larvæ in the tidal creeks in which these fish occur seems to supply sufficient evidence of their activities, and one is inclined to think that there exist in our tidal creeks sufficient quantities of larval destructors to prevent mosquitoes occurring anywhere. This is of immense value in mosquito control because it is realised that if tidal waters can be given an unrestricted passage to work their way to and fro without let or hindrance and in or out of potential breeding-places, swamps and the like then the control of such areas must be rendered comparatively simple. Brisbane waters do not possess the various species of Killifishes so successfully used in combating salt-marsh mosquitoes in New Jersey, but we believe that there are quite a number of other fish which might be successfully used in Queensland, and even now are probably instrumental in controlling such waters in which they occur.

FAMILY GOBIIDÆ—*Rhinogobius lefthorn* Ogilby—This fish, of which an illustration is given in Fig 14, occurs in salt-water tributaries of the Brisbane River, such as the Norman Creek, and assists in mosquito control in tidal waters generally. This we believe to be the case, because when kept in confinement, this fish proves itself an extremely efficient larval destructor.

MUGILOGOBIOUS DEVISI Ogilby (Fig 13) Occurs in salt-water and finds its way up the creeks of Brisbane under tidal influence. It can be accustomed to fresh water, and is known to devour mosquito larvæ voraciously. The eggs of both these species are hung on various substances, where the male guards them against the possible attack of enemies.

FAMILY MUGILIDÆ—*Mugil cephalus* L., the Sea or Mangrove Mullet, has been said by some to be larvivorous. I have kept specimens of young in aquaria, but not under any circumstances could these fish be induced to take any notice of mosquito larvæ.

TRUE LARVIVOROUS FISH INTRODUCED INTO AUSTRALIA

FAMILY PEOILIDÆ—*Lebistes reticulatus*—"Barbados Millions," sometimes called the Opal Fish (Figs 16 and 17)

Lebistes will thrive under cover, in well-balanced aquaria, provided with a thick aquatic vegetation. The chief objection to its introduction into the open in Southern Queensland lies in its inability to stand sudden changes in temperature, but for all that it can be made to have its

uses, and will winter safely among copious aquatic growth. This fish is viviparous and a very prolific breeder, and when hungry will sometimes eat its own young. Plenty of thick weeds are necessary in order to enable the young to hide. *Ceratophyllum demersum* is ideal for this purpose, though a combination of *Hydrilla verticillata* and *Valisneria spiralis* proves ideal.

This small fish wintered in the evaporation tank shown in Fig. 15 quite satisfactorily, in spite of the low temperatures to which the tank was subjected in 1928. Its ability to do this is evidence of its usefulness.

Restocking of such places as these, in case of accidents, is made quite easy by carrying over stock broods for use in the following spring. This method of control has been very successfully employed in anti-mosquito work in the Brisbane area.

GAMBUSIA AFFINIS.—The American Top Minnow (Figs. 18 and 19). These fish will thrive in fresh or brackish water, but cannot live in polluted waters. They can be accustomed to salt water without any harm. *Gambusia* is a surface feeder, and lives and thrives under a variety of conditions, but cannot stand sudden changes of temperature. Its original home is in the Mississippi Valley. (*Gambusia* is well known to aquarium lovers, and thrives in Brisbane even in the winter, so long as the water in which it lives is not subjected to any sudden drop in temperature. The fish will not, however, survive the winter in small aquaria, unless provided with copious quantities of aquatic vegetation. It is a prolific breeder, and is viviparous. Young begin to make their appearance in Queensland soon after the warmer weather of spring has set in. If plenty of food is not available, they will eat their young without compunction.)

The introduction of *Gambusia* into southern waters in Queensland seems to be fraught with some degree of risk, more particularly on account of the temporary nature of many waters, and the various natural and other enemies to which it is prone. During the summer months, however, in controlling local waters it is to be highly commended, and the carrying over stock brood for use in the following spring should make this method of control of ornamental waters very popular. In Northern Queensland this fish should be popular, and it is hard to see why it could not thrive there equally as well as it does in other tropical places of a very similar temperature.

It has been constantly argued that *Gambusia* cannot stand any degrees of frost, but we have reason to believe that this is not so. Some mosquito work recently conducted in Albania by Mrs. Sidney Loch is interesting. It transpired that the fish stood 10 degrees below zero, whilst 3 inches of ice was formed over the ponds. As long as air-holes were kept open there were apparently no losses at all. In the cold weather the fish disappear into the mud at the bottom, and though they are very lethargic and eat very little, if at all, during the winter, they become very lively as soon as the ponds are cleared of ice. With the approach of summer they fed heavily on powdered oven-dried bread and powdered sun-dried meat, and thus learnt very quickly to adapt themselves to local conditions.

HATCHERY

Figure 6 gives a very fair impression of the hatchery which has been started in connection with the Brisbane City Council's mosquito work. A large cement tank has been converted into an aquarium, and at present the Crimson-spotted Sunfish disport themselves in its waters. The aeration of the water is carried out mainly by the following plants rooted in a sandy bottom some 6 or 8 inches in depth — (1) *Hydrilla verticillata* (Water Thyme), (2) *Ceratophyllum demersum* (Hornwort), (3) *Chara fragilis*.

A number of young have hatched out this season, but it is hoped that when the fish have become better established they will feel so thoroughly at home that greater progress than has been possible up till now will be made. Such large aquaria can be used to good effect for other than Sunfish, but it seems unwise to mix the fish in view of the possible development of cannibalistic tendencies. In most outdoor aquaria, much damage is done by the presence of dragon fly larvæ. No fish-eggs are safe where these larvæ exist. We have found that large numbers of dragon flies haunt our hatchery. Sunfish are useful in keeping these natural enemies under control. It has been observed that, in aquaria where sunfish are, no young dragon fly larvæ can exist for long. The Crimson-spotted Sunfish is particularly suitable for the type of work for which it has been selected.

CONCLUSIONS

(1) The value of biological control of mosquitoes must not be overlooked. With the increase of our knowledge the subject assumes daily greater importance, and it is with the hope that some day it may come into its own that these observations are herein recorded.

(2) Close observations made during the last three years show conclusively that larval destructors are capable of exercising more than a mere check on mosquito larvæ.

(3) Larval destructors occur in very large numbers in natural waters. They abound in almost prodigious numbers in waterholes which form a portion of the bed of our local creeks isolated from the main stream in periods of dryness. They occur further in artificial waters of various kinds, where they particularly during the early part of the season are instrumental in keeping mosquitoes completely under control. Conditions exist which make larval destructors in some natural waterholes effective throughout the whole year.

(4) Particular attention is here drawn to the beneficial effects of the larval destructors in the Murrumbidgee Irrigation Area of New South Wales, where the numbers appear to be even greater than in the Brisbane district, the presence of large numbers of Chironomids providing them with large quantities of natural food for months in the year.

(5) We are very fortunate in having quite a large number of larvivorous fish in Southern Queensland capable of doing wonderful work

both in fresh, brackish, and salt water. Among these the species most highly recommended are—*Gaterricophalus fluviatilis* and *Melanotania nigrans* for fresh water, and *Pseudomugil signifer* for brackish and salt water. A distinction is drawn between lavivorous as surface feeders and larva-eating fish as bottom feeders.

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This paper is unfortunately not available to the author. A recent review, however, states that Anopheline larva in an aquarium were very extensively preyed upon by *Hydia fusca* L., and leeches are also referred to as a factor in natural control.

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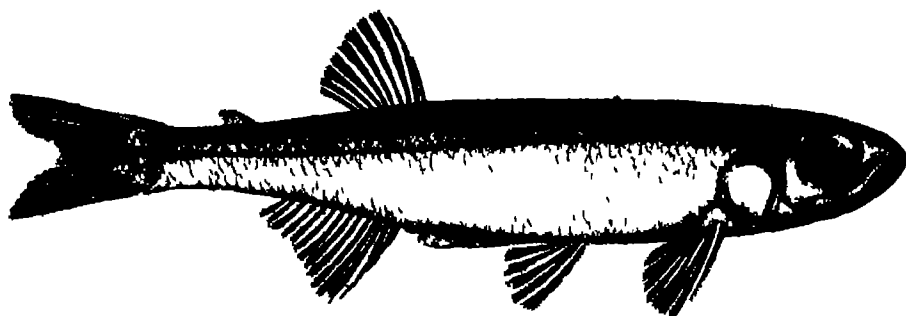


Fig 1—*Retropinna semoni* Weber. An effective mosquito destroyer (common in Brisbane waters)

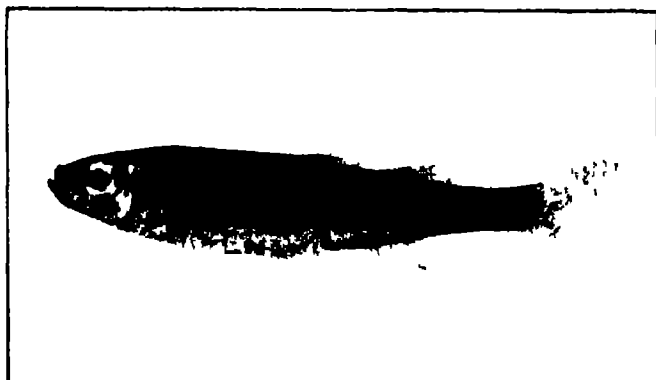


Fig 2—*Craterocephalus fluvialis* McCulloch—The Fresh water Herring. One of the most useful destructors Australia possesses

Most of the fish shown in these illustrations are from photographs taken *in life*. Some difficulty was experienced in doing this, and it may be of interest to our readers to know what method we adopted.

A solution of 2 per cent cocaine hydrochloride was prepared in 50 per cent alcohol, and small drops of this were added to the water in which the fish were placed. As the drug began to take effect slowly the fish would come to lie on their sides with fins extended in a very natural position, and, by carefully manipulating the camera from above, excellent pictures can be taken of natural history objects in this way.

The fish can be restored to a normal condition again by being placed in fresh water. By changing the water several times no ill effects seem to accompany the narcotisation, provided that the process is not unduly hastened or prolonged.

Figs 2, 3, 5, 9, 10, 11, 12, 13, 17, 18, 19 taken from life by Mr H. W. Molsby, to whom our thanks are due.

Figs 1, 13, and 14 kindly loaned by the Trustees Australian Museum.

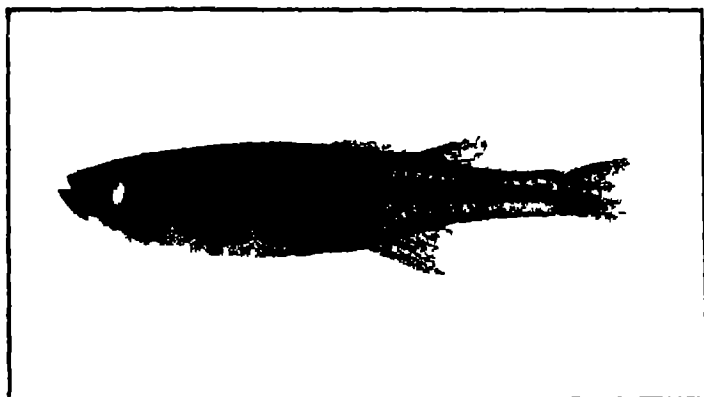


Fig. 3—*Pseudomugil signifer* Kner. The Queensland Blue eye.
Efficient in other salt, brackish, or fresh water.



Fig. 4—A Tidal Diun. A common feeding ground for Blue eyes.

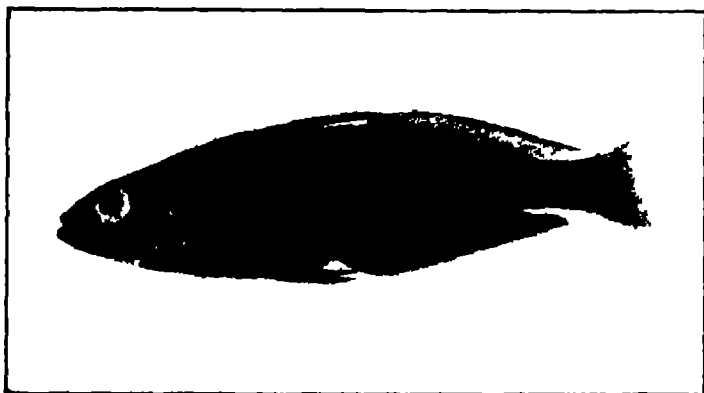


Fig. 5—*Melanotaenia nigra* Richardson. The Crimson spotted
Sunfish. Queensland's most useful larvivorous fresh water
fish.



Fig 6.—The western end of the Hatchery, situated in South Brisbane, the property of the Brisbane City Council, where the water is 4 ft 6 in. in the deepest part. Here the Crimson-spotted Sunfish is breeding and flourishing.

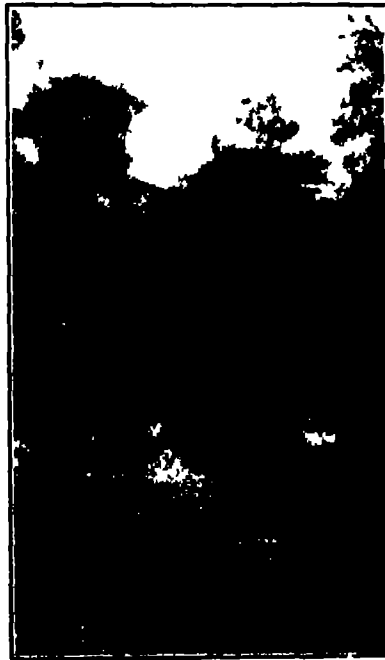


Fig 7.—A portion of the Froggera Creek. A natural home of various kinds of lavivorous fish.



Fig. 8—A quiet breeding pool of the Crimson spotted Sunfish



Fig. 9—*Protopis olivaceus* Ogilby. The Green Perchlet, a luxurious fish with cannibalistic tendencies

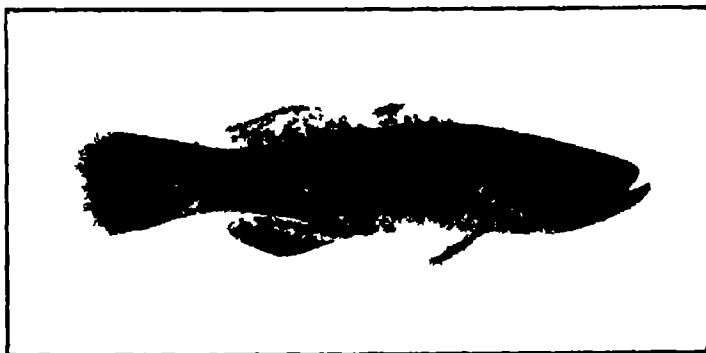


Fig. 10—*Mogurnda Mogurnda adspersus*. The Trout Gudgeon, a coarse bottom feeder

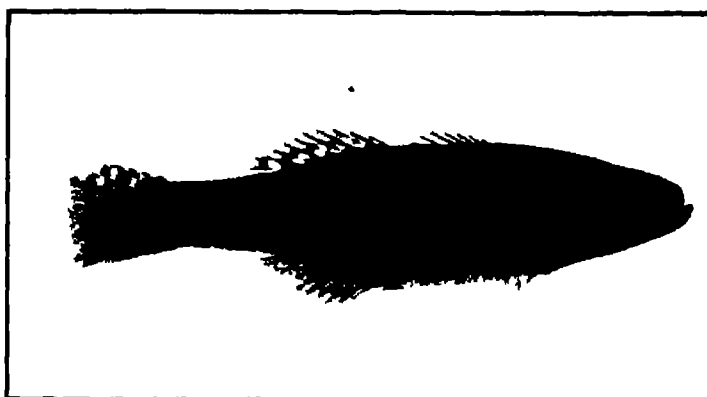


Fig. 11—*Caesiopsis compressus* Krefft. The Crisp Gudgeon (female)
An active bottom feeder of voracious type

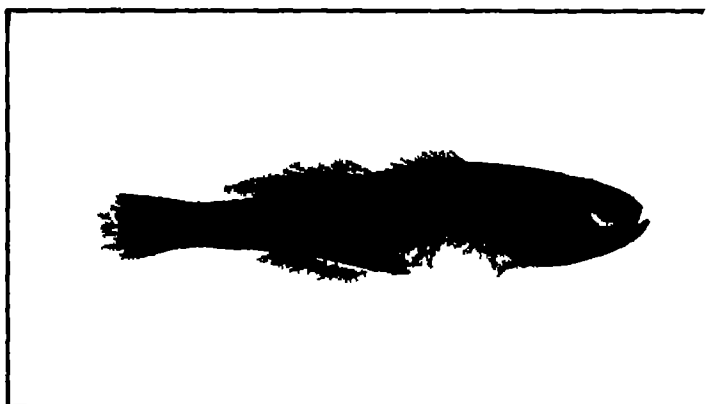


Fig. 12—*Caesiopsis gairdneri* Ogilby. The Fire tank Gudgeon

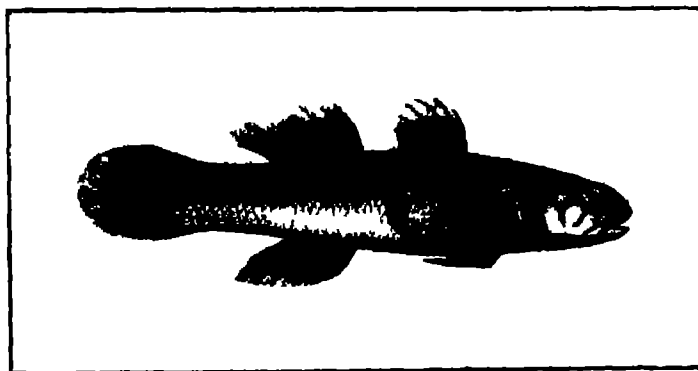


Fig. 13—*Mugilogobius decaisne* Ogilby. Suitable for mosquito control
in tidal waters

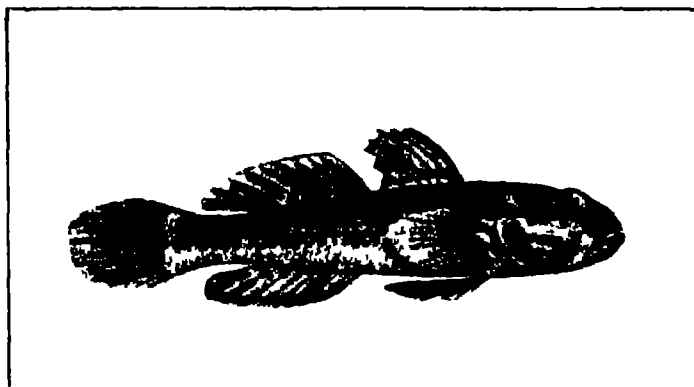


Fig 14 -- *Rhynogobius lefluctu* Ogilby Useful for salt water control



Fig 15 —An Evaporation Tank entirely controlled by
Lebistes reticulatus

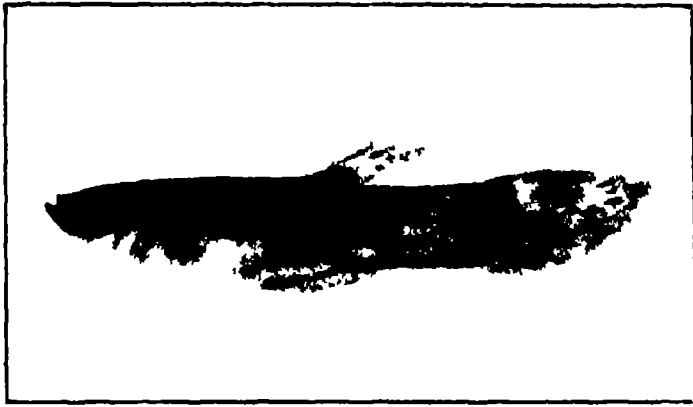


Fig 16—Male of *Lebiastes reticulatus*, 1 m in length

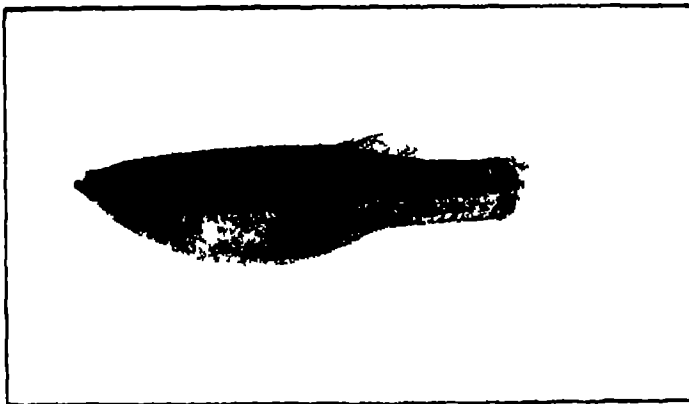


Fig 17—Female of *Lebiastes reticulatus*, 1 1/2 m in length

Cyprinodontidae (Top Minnows) Small fish which always feed near the surface. They possess the lower jaw elongated and the top of the head flattened, making them particularly suited to surface feeding.

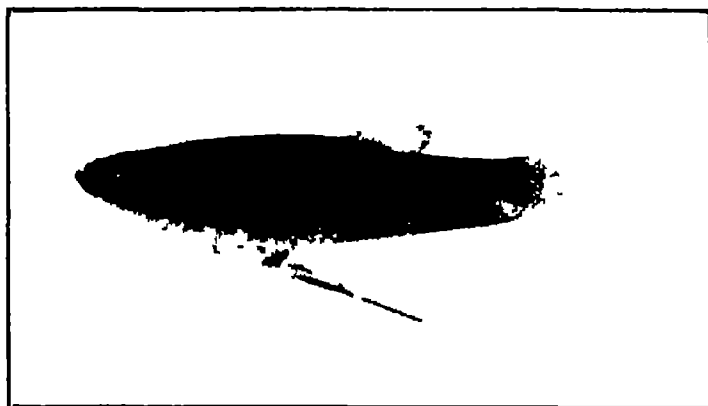


Fig 18—Male of *Gambusia affinis*, about 1 in in length

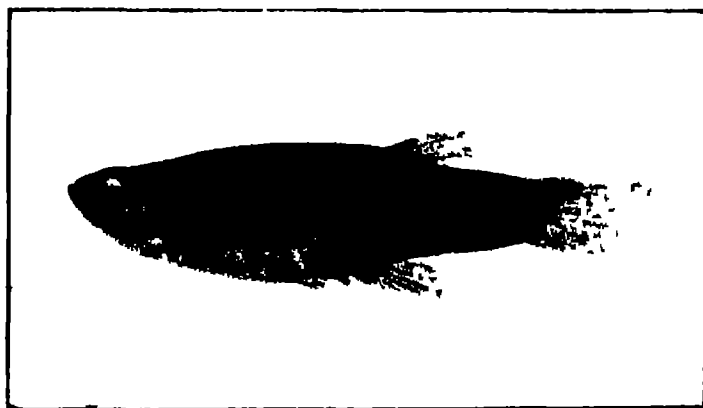


Fig 19—Female of *Gambusia affinis*, 2½ in in length

A Revision of the Queensland Bignoniaceae.

By C G G J VAN STEENIS, Botanist at the Herbarium at Buitenzorg,
Java

Two Text figures

(Communicated to the Royal Society of Queensland by C T White,
27th May, 1929)

Though the Bignoniaceae of Queensland have been established for the greater part by F von Mueller, Benthams, and Bailey, it appeared that several additions could be made after a revision of the material preserved in the Brisbane Herbarium. I am much indebted to Mr C T White, Government Botanist, who kindly put these specimens at my disposal.

Most of the species had to be cited under new combinations, in which I have followed the international rules as now adopted¹.

Tecoma has been worked out by Schumann² and by Bureau and Schumann³, they have pointed out that the true *Tecomae* are all trees with digitate leaves, and American in distribution.

Dyplanthera is a name used for a potamogetonaceous genus by Thouars⁴ four years before R. Brown published this name for the bignonian tree. So *Deplanchea* Vieillard has to be accepted, already used in Australian literature by F von Mueller in his second Systematic Census of Australian Plants.

Hausmannianthes is a new name proposed for *Hausmannia* F v M on account of the 9th main rule for botanic nomenclature,¹ which dictates that "the rules and recommendations of botanical nomenclature apply to all classes of the plant kingdom, recent and fossil, with exceptions which are expressly specified". O Posthumus⁵ in his article on *Dipteris novoguineensis* called the attention to the eldest name *Hausmannia* Dunker (1846) of a fossil genus of Dipterideae which has priority. This genus may be united later on with *Dipteris* but for the present it still exists⁶. The fact that *Hausmannia* F v M is written with two s's and *Hausmannia* Dunker with only one does not allow the use of both of them for different genera.

¹ International rules of botanic nomenclature adopted by the international botanical congresses of Vienna (1905) and Brussels (1910).

² In Engler and Prantl, Nat. Pfl. Fam. iv., 3b (1896).

³ In Martius Flora Brasiliensis, vii., pars 2 (1896-97).

⁴ See Engler and Prantl, Nachträge zum, ii iv., Teil (1897) 37.

⁵ In Reconn. des travaux botaniques néerlandaises, 25a (1928) 248.

⁶ Reiche, Die Gattung Hausmannia, Leipzig (1906).

Further I had to pay attention to *Pandorea pandorana* (= *australis*), an extremely variable species, occurring from Lombok (Lesser Sunda Islands) and New Guinea along the eastern part of Australia as far as Tasmania. Bailey⁷ gave three forms for the convenience of Queensland botanists. Indeed one may distinguish several forms, for the greater part due to the extremely variable climatic conditions under which the species grows, the species occurring in the lowland as well as in the mountains, and in dry country as well as in humid forests. The more material I examined the more I was convinced that it is certainly a single species, all intergrades between the extreme forms being present. This especially appeared after studying the many specimens present in the Brisbane Herbarium.

Not long ago Skeels has used the combination *Tecoma pandorana* for this species, the specific name of Andrews having the priority before *australis* of R. Brown. As mentioned above the genus *Tecoma* in the sense of Bentham and Hooker is composed of heterogeneous elements, and *Tecoma* has been limited to American trees with digitate leaves. Further I have reduced to it *Pandorea ceramensis* from the Moluccas and *Pandorea Poincillantha* from New Guinea, so that it ranges from the Moluccas and Lombok over New Guinea and Eastern Australia as far as Tasmania.

New Zealand is not inhabited by any bignoniaceous plant. New Caledonia has several, viz., *Dolichandrone* (1 sp.), *Deplanchea* (3 sp.), and *Pandorea* (1 sp.) as pointed out below. The Fiji Islands also seem to have one, viz., *Tecoma filicifolia* Nicholson (Dict. Gard. 4 (1887) 13), which, however, may be a cultivated one, introduced from America, and not a local endemic.

In phyto-geographical respect it may be of interest to pay attention to the fact that in the Queensland Flora nearly all the Bignoniaceæ of the whole of Australia are represented. They occur for the most part in the eastern part of the continent, or, which is much the same, in the more or less humid portions. The only species known from the drier areas in the North are the three cited *Dolichandrone*s, and justly these species show an undoubtedly xeromorphic structure. They are small crooked or scrubby trees with reduced leaf surface. The nervature is an almost curious one in respect of all other Bignoniaceæ I know. The main nerve has nearly disappeared and the primary nerves are not distinct. Moreover, the leaves and leaflets are coriaceous in contrast with the other members of this East Asiatic genus, and the phyllotaxis is quite different from that of the other species. One may meet with opposite leaves as well as whorled and scattered ones, rather rare characters in Bignoniaceæ.

As to the relations with the surrounding countries, New Caledonia and New Guinea show the nearest connection with Queensland, the former country, however, being most related with New Guinea and both differing from Queensland by the occurrence of the wide-spread *Dolichandrone spathacea* (L. F.) K. Sch., a littoral species known from the Deccan Peninsula throughout the Malayan region to New Guinea and New Caledonia. It

⁷ Queensland Flora, 4 (1901) 1133-1137.

occurs throughout the southern part of New Guinea but has not been observed even in Thursday Island and other islands of Torres Strait in Queensland territory. On the other hand none of the xerophytic Queensland species has been found in New Guinea nor in New Caledonia, though e.g. *D. alternifolia* has been collected in Thursday Island. The aberrant Australian forms, isolated from the other *Dolichandrone*s in geographical and morphological respect, I have united formerly in the subgenus *Coriacea* V St.

The two figures have been drawn by the Javanese draftman Sandiwirio of the herbarium at Buitenzorg.

I have cited also the material I saw in non Queensland herbaria, this being the more necessary as several other localities can be included in this way.

The following abbreviations have been used for denoting the herbaria of which I had the opportunity to study a smaller or greater number of specimens —

H B = Herbarium of the Botanic Gardens, Buitenzorg (Java)

H Br = Herbarium of the Botanic Gardens, Brisbane

H K = Herbarium of the Botanic Gardens, Kew

H L B = The State Herbarium, Leyden (Holland)

H P = Herbarium of the Museum d'Histoire Naturelle, Paris

H S = Herbarium of the Botanic Gardens, Singapore

TABLED STATEMENT OF THE QUEENSLAND SPECIES *

TRIBUS II — TECOMEA

* *Tecomaria* Fenzl

* 1 *capensis* (Thunb.) Fenzl

Pandorea (Endl.) Spach

1 *pandorana* (Andr.) V St

Pandorea (Endl.) Spach

2 *Baileyana* (Maid et Bak.) V St

3 *jacminoides* (Lindl.) K Sch

4 *leptophylla* (Bl.) Boerl

Tecomanthe Bail

1 *Hilli* (F v M.) V St

Hausemannianthes V St

1. *jucunda* (F v M.) V St

Dolichandrone (Fenzl.) Seem

1 *alternifolia* Seem

Dolichandrone (Fenzl.) Seem

2 *filiformis* F v M

3 *heterophylla* F v M

Deplanchea Vieill

1 *hirsuta* (Bail.) V St

2 *tetraphylla* (R Br.) F v M

KEY TO THE GENERA

- | | |
|---|---------------------------|
| 1 Lianes | 2 |
| Trees, shrubs, or rambling shrubs | 4 |
| 2 Corolla valvate in bud Leaves 3 foliolate | 4 <i>Hausemannianthes</i> |
| Corolla imbricate in bud Leaves pinnate, the upper ones often 3 foliolate | 3. |
| 3 Corolla large, 6½ cm long Calyx large, 2½ cm long, campanulate, distinctly 5 lobed Flowers in racemes | 3 <i>Tecomanthe</i> |
| Corolla small, 1 2½ cm long, rarely longer Calyx small up to 6 mm long, truncate or obscurely 5 toothed Flowers in thyrses, rarely in racemes | 2 <i>Pandorea</i> |

* Genera and species only observed in cultivation have been marked with *

- 4 Leaves simple, large, verticillate, the upper ones rarely opposite, with large cup shaped glands on the upper side on the base of the midrib Flowers yellow 6 *Deplanchea*
- Leaves simple or pinnate, if simple rather small, always eglandular, scattered, opposite or sub verticillate Flowers white or scarlet 8
- 5 Flowers white Calyx spathaceous Leaves and leaflets entire 5 *Dolichandrone*
- Flowers red Calyx campanulate, 5 toothed Leaflets serrate towards the apex 1 *Tecomaria*

1 TECOMARIA

Spach, Hist Veg Phan 9 (1840) 137 Baill, Hist Pl 10 (1891) 41, K Sch in Engl & Pr Nat Pl Fam iv, 3b (1894) 230, Bur & K Sch in Martius Fl Bras viii, pars 2 (1896 97) 307, Sprague in Dyer Fl cap iv, 2 (1904) 448, in Dyer Fl Trop Afr iv, 2 (1906) 513, non *Tecomaria* Bur, Mon (1864) 47 (*quæ est Stenolobium* D Don)

Erect or scandent shrubs, with imparipinnate leaves and dense terminal racemes of orange or scarlet flowers Calyx regular, campanulate, 5-toothed Corolla-tube narrowly funnel-shaped or almost cylindric, curved, limb markedly bilabiate Stamens 4, exserted, anther-lobes connate for the upper third part, divergent below Disk cupular Ovary bilocular, ovules 4 seriate in each cell Capsule oblong linear, much compressed parallel to the septum

Species 3, all African

1 *Tecomaria capensis* (Thunb) Spach, Hist Nat Vég 9 (1840) 137

Baill, Hist Pl 10 (1891) 41, K Sch in Engl & Pr Nat Pl Fam iv, 3b (1894) 229, K Sch & Bur in Martius Fl Bras viii, pars 2 (1896 97) 307, Sprague in Dyer Fl cap iv, 2 (1904) 448, in Dyer Fl Trop Afr iv, 2 (1906) 514, V St in Bull Jard Bot sér iii, 10 (1928) 193, *Signonia capensis* Thunb Prod (1794 1800) 105, *Tecoma capensis* Lindl, Bot Reg (1838) t 1117, DC Prod 9 (1845) 223, *Ducoudrea capensis* Bur Mon (1864) 49, *Tecomaria capensis* (Thunb) Fenzl ex V St, Dim (1927) 832

A rambling shrub 2 m or more high Branches subterete, minutely pubescent above, glabrescent below Leaves opposite, shortly petioled, 5-12 cm long, leaflets 5-9, rarely 3, shortly stalked, elliptic, orbicular or rhomboidal, more or less oblique at the base, 10-30 by 8-20 mm, terminal leaflet ovate, acuminate, 20-45 mm long, all crenate, sometimes mucronulate, glabrescent above, pilose in the axils of the nerves below (domatia) Common peduncle of the inflorescence 4-10 cm long, usually overtopping the leaves, bearing a raceme of numerous 3-florous cymes, rachis, pedicels, and calyx finely pubescent, bracts linear-subulate, 4-6 mm long, caducous Calyx tubular campanulate, strongly ribbed, tube $3\frac{1}{2}$ -5 mm long, teeth deltoid, apiculate, about 1 mm long, ciliate Corolla orange-red or scarlet, tube laterally compressed, $2\frac{1}{2}$ -3 $\frac{1}{2}$ cm long, 2 mm in diam at the base, pilose inside for the lower third, anther-lobes 3 mm long, $\frac{1}{2}$ mm broad, divergent below Stamens exserted, didynamous with a fifth rudimentary one, inserted at the middle of the tube Capsule linear, flat, $7\frac{1}{2}$ -12 $\frac{1}{2}$ cm long, 8-10 mm broad, seeds narrowly winged

Queensland Enoggera Creek, near Brisbane, C. T. White in H Br , fl iii , 1916, escaped from gardens , occurring in large patches here and there along the creek

2 PANDOREA

Spach , Hist Vég 9 (1840) 136 , Endl Gen Pl (1836 40) 711, n 4114a (sectio) , Bur in Bull Soc Bot. Fr 9 (1862) 163 , Mon (1864) 49 , Benth , Fl Austr 4 (1869) 537 , Baill , Hist Pl 10 (1891) 40 , K Sch in Engl & Pr Nat Pl Fam iv , 3b (1894) 230 , Boerl , Handl 2 (1899) 590 , Bail , Queensl Fl 4 (1901) 1173 ; Diels in Engl Jahrb 57 (1922) 498 , in Nova Guinea, 14 (1927) 294, 301 , V St , Diss (1927) 294 301 , fig 3a, b, c, 4 (geogr distr) , 5, 7, 16 (phylog relat) , V St in Bull Jard Bot sér iii , 10 (1928) 194

Small to large glabrous lianes Leaves opposite, 1 pinnate, 2-11-jugate, rarely 3-foliate at the ends of the flowering twigs, mostly 2-4-jugate, leaflets small to large, suborbicular to linear, entire or dentate Thyrses terminal, often foliate at the base, rarely on the stems, peduncle often with opposite or verticillate often connate scaly bracts at the base Flowers small, 1-2½ cm long, rarely 5 7½ cm long Calyx always small, truncate or shortly 5-dentate, campanulate or mostly cupular Corolla with a lower narrow-cylindric part, inside bearded at the anterior portion or rarely glabrous, tube infundibuliformous or subcampanulate in the upper part, straight or curved, unequally 5 lobed, bilabiate Stamens 4, didynamous with a fifth rudimentary one, filaments filiform, mostly curved, the anthers touching each other Ovary oblong, bilocular with 2 placentas in each cell, each placenta with numerous ovules in many rows Capsule elliptic-oblong or somewhat curved, acuminate at the tip and ouncate at the base, valves equal or subequal, boat-shaped, smooth, coriaceous to firmly coriaceous, seeds numerous, flat, thin-membranously winged

Species 7, distributed from Ceram and Lombok, New Guinea and East Australia, to Tasmania, and New Caledonia

- 1 Corolla large, hypocraterumorphous, 4-5 cm long, outside papillose pubescent, creamy or pale rose streaked with carmine in the throat Calyx cupular campanulate truncate or obscurely 5 toothed, 6 mm long

2 *P. jasminoides*

- Corolla small, 1-2½ cm long, tube campanulately enlarged from the lower cylindric part or tubular Calyx up to 3 mm long

2

- 2 Corolla tubular, with 5 very short lobes, tube often curved, 1½ cm long and 3 mm in diam Leaves 3-jugate, leaflets large, elliptic-oblong or obovate, 12½ by 6 cm, coriaceous Primary nerves in 6-7 pairs, nerves and reticulations distinctly prominent

3 *P. Baileyana*

- Corolla with a narrow tubular part and campanulately enlarged towards the throat, 1-2½ cm long, 6-15 mm broad Leaves linear to suborbicular Extremely variable species, but nerves and reticulations never distinctly prominent, even often lacking, and leaflets mostly much smaller

1 *P. pandorana*

1. *Pandorea pandorana* (Andr) V St in Bull Jard Bot sér iii , 10 (1928)

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Bignonia Pandorana Andr , Bot Rep (1801) t 81 , *Bignonia pandorea* Vint , Jard Malm (1803) t 43 , *Bignonia pandora* Sims in Bot Mag 21 (1805) 865 ; *Tecoma quadriloba*

R. Br., Prod (1810) 471, reprint 2 (1827) 327, DC Prod 9 (1845) 225, Benth, Fl. Austr. 4 (1869) 537, F v M., Syst. Cens. 1 (1882) 99, ed. n., 1 (1889) 166, Bailey, Queensl. Fl. 4 (1901) 1134, Compr. Cat. (1909) 364, Maud. & Camph., Fl. Pl. Ferns N.S.W., n. 11, *Bignonia australis* Art., Hort. Kew. ed. n., 4 (1814) 34, *Bignonia meonantha* Link., Enum. Hort. Berol. 2 (1822) 230, *Tecoma diversifolia* G. Don, Syst. 4 (1838) 224, *Tecoma meonantha* G. Don, Syst. 4 (1838) 224, *Pandorea australis* Spach., Hist. Nat. Vég. 9 (1840) 136, K. Sch. in Engl. & Pr. Nat. Pl. Fam. iv, 3b (1894) 230; Diels in Engl. Jahrb. 57 (1922) 408, V. St. in Nova Guinea 14 (1927) 302, Duss (1927) 859, fig. 3e, 4 (10) (geogr. distr.), 16 (phylog. relat.), *Tecoma floribunda* Cunn. ex DC. Prod. 9 (1845) 225, *Tecoma Oxleyi* Cunn. ex DC. Prod. 9 (1845) 225, J. M. Black in Transact. Roy. Soc. South Austr., vol. 39, p. 836, White & Francis in Proc. Roy. Soc. Queensl. 37 (1926) 166, *Tecoma ceramensis* T. & B. in Nat. Tijdschr. Ned. Ind. 25 (1863) 412, Miq. Ann. 1 (1864) 197, t. 5. Scheffer in Ann. Jard. Bot. 1 (1876) 40, *Pandorea ceramua* (T. & B.) Baill., Hist. Pl. 10 (1891) 40, K. Sch. in Engl. & Pr. Nat. Pl. Fam. iv, 3b (1894) 230, Boerl., Handl. 2 (1899) 600, V. St. in Nova Guinea 14 (1927) 302, Duss (1927) 852, fig. 4 (6) (geogr. distr.), 16 (phylog. relat.), *Tecoma pandorana* Skeels in U.S. Dep. Agric. Bur. Pl. Ind. 62 (1913) 62, *Bignonia Poincillantha* Zipp. nomen in Herb. Lugd. Bat. ex V. St. Duss (1927) 302, *Pandorea Poincillantha* V. St. in Nova Guinea 14 (1927) 302, Duss (1927) 857, fig. 4 (9) (geogr. distr.), 16 (phylog. relat.), incl. var. *fragrans* V. St. l.c., *Tecoma Latrobei* F. v. M. ex V. St. Duss (1927) 859, nomen in Herb. Paris.

Small or large glabrous woody climber, 2-6 m. high (or more?), with twining branchlets. Leaves extremely variable, 5-20 cm. long, 1-4-7-jugate, rachis subangular to marginate or even slightly winged, especially towards the apex, leaflets mostly subaequal, except the longer petiolulate terminal one, from nearly orbicular (and then mostly 1-jugate) to linear (and then mostly 4-7-jugate), rounded, obtuse, acute or even cuspidate at the apex, papyraceous to subcoriaceous, entire or coarsely crenate, 2-8 cm. long, 2-40 mm. broad, mostly perforately glandular on the underside, side-nerves absent or 3-7, mostly indistinctly prominent, reticulations often obscure or absent. Thyrses glabrous or puberulous, dense- or lax-flowered, 7-20 cm. long, long or short peduncled, mostly leafy at the base, or only with reduced leaves, rarely nearly reduced to racemes (and then the leaflets mostly linear or linear-lanceolate). Flowers very variable in size, 1-2½ cm. long, on pedicels 5-10 mm. long. Calyx glabrous or puberulous, 2-3 mm. long, cupular, truncate or 5-toothed sometimes with distinct lobes, teeth broadly triangular, mostly ciliate. Corolla creamy or white, streaked with red in the throat and at the base of the lobes, often with red spots on the bases of the three anterior lobes, rarely yellow or yellowish with darker throat, tube infundibuliformous to campanulate, sometimes ventricose, glabrous outside, inside bearded on one side, limb zygomorphic, puberulous on both sides, anterior lobes bearded at their base. Stamens 4, didynamous, included, filaments curved, glandularly hairy at the base, anther-cells divaricate. Disk annular. Ovary sub-compressed, often glandular, 2-celled, each cell with 2 placentas, each placenta bearing numerous ovules in many rows. Capsule 3-7½ cm. long, oblong, acute or slightly acuminate at both ends, sometimes rostrate at the apex, straight or somewhat curved, valves firmly coriaceous, boat-shaped, septum thickened, seeds flat, oblong or rounded, surrounded by a transparent wing.

Distribution from Lombok, Ceram, and New Guinea to East Australia and Tasmania.

Queensland Rockingham Bay, Dallachy in HLB, HP, HU, Moreton Bay, F v Mueller in HLB sub n 900 81 135, HP, HU; Anstraha Felix, F v Mueller in HLB, HP, HU, Burdekin River, F. v. Mueller in HP, same locality, ex Herb Beaudoin in HP, same locality, Banks and Solander in HP, Herberton, J F Bailey (F M Bailey, 1c); Neerkol Creek, Bowman in HB, cultivated in Brisbane Garden, Mn in HBr, without locality, Mrs Helms in HBr, Jale River, R C Burton in HBr, S W. Dodd (Kga Nursery), F M Bailey in HBr, Eldsvold, T L Banoroff in HBr, Mt Lookout, Suttor River, Miss F Clemenson in HBr, Stanthorpe, H Wight in HBr, same locality, T Davidson in HBr, Cape York, E W Bick in HBr, Moreton Bay, without coll in HB, Bunya Mountains, C T White in HBr, Blackall Range, C T White in HBr, Innisfail, N Michael 44 in HB, Kilooy, C England in HBr, Bowen, N Michael in HBr, Eungella Range via Mackay, W D Francis in HBr, Yarraman, M A Cameron in HBr, Sinai, Oakview, F Reynolds 27, 28 in HBr, Russell Island, Miss E N Parker in HBr, Townsville, N Michael 490 in HBr, 352 in HB, Tiger Scrub, Orallo, Dunlop in HBr, Mt Perry, J Keys 570 in HBr, Bundaberg, without coll in HBr, Crow's Nest, F H Kenny in HBr, Walsh River, T Barolay Miller in HBr, Wellington Point, J Wedd 168 in HBr, Brisbane River, F M Bailey in HBr, Herberton, N Michael in HBr, J F Bailey in HBr, Paroo-Bulloo watershed, near Adavale, W MacGillivray in HBr, Port Denison, Fitzalan 898 in HLB 200 63, 200-65

New South Wales Port Jackson near Sydney in HLB sub n 898 200-68, Blue Mountains near Sydney, in HP, Wingham, J L Boorman in HLB sub n 910 151-539, Paterson River, J L Boorman in HLB sub n 908 146-2205, Australia Felix, F v Mueller in HU, Port Jackson, Lhotaky in HP, near Sydney, Arnony 44 in HP, same locality, R Brown in HP, New South Wales, M Busseuil in HP, Sydney, M Verreaux 53 in HP, Port Jackson, Beaudoin 68 in HP, without locality, A Cunningham 386 in HU, Coolabah, J L Boorman in HLB, Maiden and Boorman in HP, New England district, Miss F B May in HBr, Taronga near Sydney, Docters van Leeuwen 7255 in HB, Bantry and Manly, J H Forrest in HBr, Byron Bay, J L Boorman in HBr, Manly, J H Forest in HBr, Cowra, R Gemell in HBr, Genoa River, A Mar and Tailor in HLB sub n 898 200-96

Victoria Victoria, Duncan in HP, without locality in HLB sub n 898 200-61, Hume River, F v Mueller in HS

Tasmania Without locality in HP

This species is exceedingly variable in all kinds of characters. The leaves vary from 1-jugate with large obtuse ovate leaflets to 5-7-jugate with linear ones with all desirable intergrades even on the same twig. The colour of the corolla is most times described as creamy and red streaked inside, being odorless, sweet-scented, or disagreeably smelling. The length of the corolla varies from 1 to 2.7 cm the lobes included. The nervature is distinct in the broader and larger leaflets but is absent in the narrow-lanceolate and linear ones.

Notwithstanding these variable characters it does not seem possible to me to distinguish distinct varieties or subspecies, as all combinations of characters are present in the many specimens preserved in the Brisbane Herbarium. I saw the same thing in the Herbaria at Paris, Leyden, Utrecht, and Buitenzorg. I kept the forms or varieties of Bailey in my dissertation as subspecies, because I accept a variety in cases where a single hereditary character is present or absent. After having seen the rich material at Brisbane the distinction of subspecies also seems to me of no use here.

When cultivating the aberrant forms in Queensland it may certainly appear that some are constant, but in that case the number of these forms will be very great, and such a division can hardly be based on herbarium material. Moreover *P. australis* cannot be mistaken for the other Australian *Tecoma*, being quite sharply separated from them.

The most curious forms are those with linear leaflets without nerves and a more or less broadly winged leaf-rachis. But even this form is connected to those with lanceolate leaflets by intermediate forms, e.g., by the specimens from Stanthorpe (H. Wright), and Russell Island (Miss E. N. Parker).

In a report on a collection of plants from the north-western region of South Australia made by Captain S. A. White, *Tecoma Ozleyi* was separated by J. M. Black from *T. australis* (Transact. Roy. Soc. South Austr., vol. 39, p. 836), in which he is followed by J. H. Maiden in his Census of New South Wales Plants. I think it not possible to distinguish specific characters, though it may be a conspicuous form if treated locally. Specimens with narrow leaflets (evidently from arid places, xerophytes) may have small or large flowers.

The leaves of youth-forms show a striking resemblance to those of *Pandorea leptophylla* (Bl.) Boerl., though there are fewer leaflets. See also note under "Excluded Species" at the end.

[2. *Pandorea Baileyana* (Maid & Bak.) V. St., Diss. (1927) 849, fig. 4 (4) (geogr. distr.), 16 (phylog. relat.)]

Tecoma Baileyana Maid & Bak. in Proc. Linn. Soc. N. S. Wales, ser. 4, 10 (1895) 592, pl. 51, Bail., Queensl. Fl. 4 (1901) 1134, Compr. Cat. (1909) 364, Fig. 1.

Tall woody glabrous climber. Leaves 1-pinnate, 3-4-jugate, sometimes exceeding 60 cm., mostly 15-25 cm. long. Branchlets 4 mm. in diameter. Petioles thickened at the base, 3.5-7½ cm. long, subterete, leaf-scars connected by a prominent line, rachis thickened near the insertions of the thickened bases of the petiolules, leaflets entire, nearly sessile, broad-oblong, acuminate, base oblique, rounded or slightly tapering, chartaceous or subcoriaceous, side-nerves 10-11, distinctly prominent on the underside as the reticulations, shining dark green above, dull pale green beneath. Inflorescence thyrsoid, paniculiformous, rather many-flowered, axillary, 7½-45 cm. long, mostly 15-20 cm.; peduncle terete, 2½ mm. in diam.; primary stalks 2-3 cm. long, 7-flowered on the average. Calyx articulate with a hypanthium, truncate, irregularly lobed or more or less distinctly 5-lobed, 3 by 4 mm., smooth, glabrous, purplish brown. Corolla tubular,

curved, 12-13 mm long, shortly papulose-pubescent outside, cream-coloured, lobes and throat shaded with pink tube inside somewhat bubbled, slightly hairy, lobes almost equal, suborbicular, densely papulose-pubescent Stamens 4, included, glabrous, anther-cells ovate-oblong Ovary sub-orbicular or ovate, style glabrous, exceeding the stamens, stigmatic lobes suborbicular crenate Capsule unknown



Fig 1 —*Pandorea Baileyaana* Leaf and inflorescence (after Richmond River in H Br), x 5/12

New South Wales Mullumbimby Creek, Tweed River, W Bauerlen (type), Richmond River, without coll in H Br , Mullumbimby, W Bauerlen in H Br , H K

This rare endemic Australian species is most nearly related to *P stenantha* from New Guinea on account of its leaves and flowers. I have not observed verticillate leaves as mentioned by Maiden and Baker in their original description (copied by Bailey 10), but abnormal flowers sometimes occur.

Mr C T White writes that though this species was recorded by Bailey l c as "near the Tweed River, W Bauerlen" it has not yet actually been collected in Queensland territory, though possibly it grows there. Mr Bauerlen's specimens were collected at Mullumbimby in New South Wales territory. As the species grows not very far from the Queensland border, and is further one of the only two Australian members of the family not found in Queensland, it is inserted here for the purpose of convenience.]

3 *Pandorea jasminoides* (Lindl) K Sch in Engl & Pr Nat, Pfl Fam iv, 3b (1894) 230

V St in Nova Guinea, 14 (1927) 302, Dias (1927) 847, fig 4 (3) (geogr distr) 16 (phylog relat), in Bull Jard Bot sér iii, 10 (1928) 195, *Tecoma jasminoides* Lindl Bot Reg (1838) t 2002, DC Prod 9 (1845) 225, Cunningham in Loud Hort Brit p 582, Don, Gard Dict 4 (1838) 225 Bot Mag t 4004, Benth, Fl Austr 4 (1860) 537, F v Mueller, Syst Cens 1 (1862) 99, col ii, 1 (1889) 166, Bailey, Queensl Fl 4 (1901) 1134, Compr Cat (1909) 364

Tall glabrous woody climber, ultimate branchlets terete, denticellate. Leaves opposite, 1 pinnate, 2-3 (4)-jugate. Leaflets nearly sessile, the terminal one on a petiolule 10-15 mm long ovate to lanceolate, obtuse-acuminate, shining, entire, slightly concave at the base, $2\frac{1}{2}$ -5 by 1-2 cm, or in ovate leaflets 3-5 by $1\frac{1}{2}$ -2 $\frac{1}{2}$ cm. Nerves in 3-5 pairs, very indistinct, reticulations none or minute, underside microscopically punctate. Thyrses terminal, subcorymbose, compact, 6 cm long including the peduncle 3 cm long. Flowers large, showy. Calyx glabrous, glandular, 6 by 5 mm, truncate or rarely obscurely 5-toothed, teeth equal, broad-triangular, acute. Corolla infundibuliformous campanulate, delicately milk-white and streaked with carmine in the throat, 4-5 cm long, shortly papillose pubescent outside, tube 8-10 mm broad, inside bearded near the insertions of the stamens at 5 mm above the base, limb flat, expanded, lobes 5, rounded, somewhat wavy and crenate, very broad, half as long as the tube, pubescent inside, throat scarcely bearded or marked inside with 2 decurrent lines, short hairs. Stamens 4, a fifth rudimentary one, included, filaments glabrous. Disk annular cupuliformous. Ovary 2 celled, each cell with two indistinctly separated placentas, ovules numerous in many series on each placenta, stigma bilamellate. Capsule oblong, mostly elliptic, acute or slightly acuminate at both ends, smooth, 5-10 cm long, valves thickly coriaceous, boat shaped, seeds flat, obcordate, with broad transparent wings.

Queensland Moreton Bay, Cunningham (Bailey l c), C T White in H Br, Brisbane River, F v Mueller (in lit), F M Bailey in H Br, Burdekin River, F v Mueller (l c), Ipswich, Nernst (Bailey l c), Brookfield, F M Bailey in H Br, Eumundi, F M Bailey in H Br, Rosewood, C T White in H Br, Taylor's Range near Brisbane, C T White in H Br, Bunya Mountains, C T White in H Br, Eungella Range via Mackay, W D Francis in H Br, Fraser Island, F C Epps in H Br, Blackall Range, C J Gwyther in H Br.

New South Wales Richmond River, Henderson (Bailey l c), Clarence River, Beckler? (Benth l c)

This beautiful climber differs distinctly from the other *Pandoreas* by its large corolla and smooth leaves. It is often cultivated in the tropical regions and is used as a greenhouse plant in the temperate ones.

3 TECOMANTHE

Baill, Hist Pl 10 (1891) 41, K Sch in Engl & Pr Nat Pfl Fam iv 3b (1894) 230, Boerl, Handl 2 (1901) 590, Diels in Engl Jahrb 37 (1922) 496, V St in Nova Guinea 14 (1927) 294, Diss (1927) 864, in Bull Jard Bot ser iii 10 (1928) 201

Tall rarely low climbers, stem woody, sometimes with pendent roots inserted near the leaf scars, but apparently not climbing by them. Leaves opposite, 1-5-jugate, leaf scars connected by a prominent line, leaflets opposite, sessile or shortly petiolulate, the terminal one mostly longer petiolulate, papyraceous to coriaceous, mostly totally glabrous, entire or dentate in the upper half. Flowers in axillary racemes, rarely in axillary thyrses (*T. montana* and *T. varosa*), solitary or rarely 2 or 3 in the axils of the leaves or mostly on the old wood in the axils of leaf scars, mostly shorter than 5 cm, seldom longer. Peduncle at the ultimate base with scale-like bracts, rarely with reduced leaves, pedicels with a bract and 2 bracteoles. Calyx campanulate, rarely subtricolate, large, mostly 2½-4 cm long, with 5 eglandular large lobes, rarely smaller (*T. montana*) or subtruncate (*T. aurantiaca*). Corolla large, 5-10 cm long, rarely smaller (*T. montana*), straight or curved, glabrous or puberulous at the apex red, reddish, or rarely orange, tube below with a narrow inside pubescent part, infundibuliformous enlarged above, 5-lobed, lobes large mostly distinct unequal. Stamens 4, didynamous, with a fifth rudimentary one. Disk annular. Ovary 2-locular, each cell having 2 placentas on the dissepiment or the placentas are inserted in the corners of wall and septum, ovules in many rows on each placenta. Capsule bilocular with 2 coriaceous boat-shaped valves, seeds unknown.

Distributed from Ternate to Queensland, species 16

In Queensland only one species—1 *T. Hillii*

1. *Tecomantthe Hillii* (F v M) V St, Diss (1927), 894

Tecoma Hillii F v M, Fragm 10 (1877) 101. Bailey, Queensl Fl 4 (1901) 1133, Compr Cat (1909) 364, C T White in Queensland Naturalist, vol 4 (1920) 99-101, with figure showing flowers and fruit

Tall glabrous climber, 3 m high with a similar diameter. Leaves 1-pinnate, leaflets 5, oblong lanceolate, 2.5-7.5 cm long, rather thin, oblique at the base. Flowers abundant, racemes 6-flowered. Calyx 12½-25 mm long, membranous. Corolla 5-7½ cm long, limb rosy purplish, tube pale, marked with purplish lines, lobes 6-8 mm long, pubescent towards the margins. Stamens 4, didynamous, filaments filiform, anthers yellow, cells equal, 3-4 mm long, widely divergent, staminodium 4-6 mm long. Ovary compressed, style filiform, glabrous, stigmatic lobes sublanceolate. Capsule 3.75 cm long.

Queensland Fraser Island, W R Petrie in H Br , Hervey Bay, F Turner in H Br

Cultivated in the Brisbane Gardens, F M Bailey in H Br

The only endemic and Australian species of this genus, allied to the New Guinean *T. venusta* and *T. cycloperensis*. The figured leaf is not quite of the normal type. The lowest leaflets are both divided into two unequal ones, one small lower-inserted one and the proper oblique one. Without doubt it is a true *Tecomanthus* on account of its raceme of large flowers. One of the flowers on the right shows a very peculiar aberrative structure. The calyx and corolla form a connate torted spatha with 10 gradually higher-inserted lobes, the upper portion being corolla-like.



Fig 2—*Tecomanthus Hillii* (? Normal) leaf and inflorescence (after W R Petrie in H Br), x 4/7, transverse section of the ovary, magnified

4. HAUSSMANNIANTHES

Van Steenis, nom. nov. *Haussmannia* F v M, *Fragm.* 4 (1864) 148, non Dunker (1846), Benth, *Fl. Austr.* 4 (1869) 539, Benth & Hook, *Gen. Pl.* 2 (1876) 1041, F v M, *Syst. Cens.* 1 (1882) 99, ed. II, 1 (1889) 167, Baill, *Hist. Pl.* 10 (1891) 21, note 2, K. Sch. in *Engl. & Pr. Nat. Pfl. Fam.* IV, 3b (1894) 223, Bailey in *Bot. Bull.* n. 13, *Departm. Agric. Queensl.* 11, *Queensl. Fl.* 4 (1901) 1136, *Compr. Cat.* (1909) 368, fig. 345, V. St. Dias (1927) 901, fig. 5 a, t. 7 (2) (geogr. distr.), 16 (phylog. relat.), *Nyctocalos* (subgenus *Haussmannia*) Seem. in *Journ. Bot.* 8 (1870) 149.

High climber with opposite, 3-foliate, pinnate leaves, without tendrils. Leaflets entire. Thyrses terminal or lateral, or terminal with reduced leaves at the base. Flowers pedicellate. Calyx campanulate, truncate or

5-toothed Corolla tubular, bilabiate, 5-lobed, lobes induplicate-valvate in bud Stamens 4, didynamous, the fifth rudimentary, all of them exerted Disk cupular, enclosing the ovary Ovary bilocular with a transverse dissepiment, ovules numerous, in several rows on 2 placentas, style with 2 stigmatic lobes Capsule oblong, opening by 2 concave valves as in *Pandorea* and *Tecomanthé*, acuminate, seeds numerous, broad-membranously winged, septum broad, thick, perpendicular to the valves

Monotypic genus Endemic

1. *Hausmannianthes jucunda* (F v M) V St, comb nov

Hausmannia jucunda F v M, *Fragm* 4 (1869) 539, *Bailev in Bot Bull* n 13, *Departm Agric Queensl* (1896) 11, *Queensl Fl* 4 (1901) 1136, *Compr Cat* (1909) 368, *Fig* 345, V St, *Diss* (1927) 902, *fig* 5 a, t

Tall, glabrous, luxuriant climber, with terete branchlets Lower leaves rarely 1-foliate, shining on both sides with a rather long slightly striate petiole, 4-6 cm long, leaflets concave, subcoriaceous, articulate at the end of the petiole, ovate or oblong, narrowed into the petiolules, lateral ones 5-10 mm, terminal one 2½ cm long, petiolulate, terminal leaflet sometimes confluent with one of the lateral ones, blade 9-11 by 4-5 cm, side-nerves 8-10, curved, patent, reticulately connected, prominent below, lax Flowers rapidly dropping Thyrses 5-15 cm long, rather few flowered, cymes 6-20 mm long, opposite, 2-5-flowered, bracts small, lanceolate, pedicels 4-6 mm, bracteoles minute or absent Calyx 4-6 mm long, glabrous, subcoriaceous, lobes 5, equal, broad-triangular, 2 mm long Corolla pinkish purplish, incurved, tube 2-2½ cm long (lob excl), slightly dilated above the calyx, lobes broad ovate, 5 mm long, hairy inside, arranged in 2 lips Filaments hairy at their insertions, inserted below the middle of the tube, exceeding the corolla 7-10 mm, anther cells divergent or divaricate Disk 2 mm long Ovary short, slightly compressed Capsule 7½-15 by 3½ cm, acuminate at both ends, smooth, valves sometimes with a nipple shaped minute appendix near the top, septum broad, thick and firmly attached to both valves or to one of them, seeds pyriform, wrinkled, broad-transparently winged, wings 1 cm broad

Queensland Thursday Island, E Cowley (Bailey in lit), Redlynch road near Cairns, E Cowley in H Br, common, Atherton, F M Bailey in H Br, Johnstone River, G H Ladbroke 65 in H Br, Freshwater Creek, Cairns, L J Nugent (Bailey l c), Stony Creek, Cairns, L J Nugent (Bailey l c), Harvey's Creek and Mulgrave River, F M Bailey (Bollenden-Ker Exped) in H Br, Seaview Range, Rockingham Bay, Dallachy in H L B sub n 898, 199-71, H P, type specimen, Rockingham Bay, F v Mueller in H L B sub n 898, 199-70, H P

Cultivated in the Botanic Gardens at Brisbane, F M Bailey in H Br

This climber seems to be rather common in the scrub, but fruiting specimens have rarely been collected Its relations are to be found among *Pandorea*, *Tecomanthé*, and especially in *Neosepicaea*, a New Guinean

climber All these genera show the same structure of the capsule It is easily distinguished by the valvate corolla, the exserted stamens, and the oipular disk

5 DOLICHANDRONE

Seem in Ann Mag Nat Hist ser iii 10 (1862) 31, in Journ Bot 1 (1863) 236, 8 (1870) 379 Benth & Hook, Gen Pl 2 (1876) 1046 (near *Markhamia* or *Muensteria* excol), Baill, Hist Pl 10 (1891) 48, K Sch in Engl & Pr Nat Pl Fam iv, 3b (1894) 240, Sprague in Kew Bull (1919) 303, V St Dias (1927) 928 fig 3 J 10, 11 (geogr distr), *Dolichandrone* (section) Fenzl in Denkschr Kaiser Bot Ges Regensburg, 3 (1841) 113, 265, *Spathodea* R Br, Prod (1810) 471, Bur, Mon (1864) 50 t 27, non Beauv

Trees with pinnate or simple, opposite, pseudo-verticillate or scattered leaves, leaflets elliptic to filiform, entire or denticulate Flowers in terminal racemes or thyrses nocturnal, fragrant Calyx spathaceous, almost arcuate Corolla white, the lower part of tube long funnel shaped, much exceeding the calyx limb subequally 5-lobed, mostly crispate or dentate Stamens 4, didynamous with a fifth rudimentary one inserted in the throat, anthers glabrous, bilocular Disk annular, cushion shaped Ovary sessile with numerous ovules in many rows Capsule subcylindric or compressed siliquiform, often spirally twisted, elongate, loculicidal, pseudo quadrilocular owing to an incomplete false septum Seeds in 4 rows in each cell, corky or membranously winged

Species 9, from East Africa to S E Asia, North Australia and New Caledonia Type species *D. spathacea* (L F) K Sch All species of the sub genus *Coriacea* V St are endemic in Australia, of the *Membranaceae* V St not a single species has been found there

CORIACEAE V St, Dias (1927) 931

Small scrubby glabrous trees Leaves simple or 1 pinnate, scattered, opposite or verticillate, leaflets coriaceous, mostly lanceolate or linear, with \pm parallel equal prominent primary secondary, and tertiary nerves

- | | |
|--|--------------------------|
| 1 Leaves and leaflets filiform | 1 <i>D. filiformis</i> |
| Leaves or leaflets broader | 2 |
| 2 Leaves simple, ovate, mostly scattered or irregularly opposite | 2 <i>D. alternifolia</i> |
| Leaves simple or 1 3 jugate, lanceolate or linear scattered, opposite or mostly in whorls of 3 | 3 <i>D. heterophylla</i> |

[1. *Dolichandrone filiformis* F v M, Fragm 4 (1864) 140, in obs

Seem in Journ Bot 8 (1870) 383, F v M Syst Cens (1882) 99, ed ii, 1 (1889) 167, Sprague in Kew Bull (1919) 304 V St Dias (1927) 931 fig 10c, 11 (d) (geogr distr) *Stereospermum filiforme* DC in Bibl Univ Gen (1838) *Bignonia filiformis* A Cunn in Ann Sc Nat, ser ii, 9 (1839) 280, nomen, *Spathodea filiformis* DC Prod 9 (1845) 240 Benth, Fl Austr 4 (1869) 539 Ewart & Davies, Pl North Terr p 250, Bailey, Queensl Fl 4 (1901)

Small glabrous tree Leaves irregularly 3-verticillate, irregularly opposite or scattered, pinnate, 1-3-jugate, rachis terete, leaflets filiform, terete, 15-25 cm long and distant or more crowded and shorter Racemes terminal, few-flowered, 5-10 cm long, shorter than in *D. heterophylla*, pedicels elongate, 3-5 cm long, longer than in *D. heterophylla* Calyx

glabrous, smooth, spathaceous, 1½-2 cm long, arcuate Corolla white, ca 5 cm long, glandular, tube narrow, lobes undulate-dentate Ovary glabrous Capsule subcylindric when dry, terete when fresh, arcuate, up to 25 cm long, glabrous, seeds as in *D heterophylla*

North Australia Mt Essington, Leichhardt in H P Victoria River, F v Mueller in H P, Copeland Island, A Cunningham in Herb Cook (Seem 1c)

Not yet collected in Queensland, but recorded here for the purpose of convenience, as one of the only two non-Queensland members of the family]

2 *Dolichandrone alternifolia* Seem in Journ Bot 8 (1870) 340, 382

Benth & Hook, Gen Pl 2 (1876) 1046, Sprague in Kew Bull (1919) 304, V St, Duss (1927) 934 fig 10a, 3 f, 11 (1) (geogr distr) *Spathodea alternifolia* R Br, Prod. (1810) 472 DC Prod 9 (1845) 209, Benth, Fl Austr 4 (1869) 539, Bailey, Class Ind Pl Queensl Fl 4 (1901) 1135, Compr Cat (1909) 368, *Dolichandrone heterophylla* F v M, Fragm 4 (1864) 149, partim, *Dolichandrone Brunonis* F v M, nomen in Herb Paris, ex V St, Duss (1927) 935

Small tree Branchlets terete, smooth Leaves scattered, alternate or irregularly opposite, coriaceous, entire, ovate or broadly ovate lanceolate, at the base narrowed into the long petiole, obtuse or acuminate, sometimes emarginate up to 8-9 by 4.5 cm, veins oblique Flowers unknown to me Capsule arcuate, to 30 cm long, flat, smooth, slightly acuminate, seeds rather narrow, including the wings 3 cm long, germ 10 by 5 mm

North Australia Gulf of Carpentaria, without coll in H P

Queensland Endeavour River, Banks and Solander (Benth 1c), Burdekin River, F v Mueller (Benth 1c), Upper Lynd, Leichhardt in H P, Rockingham Bay, Dallachy (Sprague 1c) between Cleveland Bay and Rockingham Bay, Hill (Sprague 1c), Thursday Island, Jaher in H B, fr 19 v 1901, without locality, T Barclay Miller, 33 in H Br, shrub or tree, runs 6-14 ft high, all over the country, cattle and horses are very fond of it and break it down, Gulf country, D 4, T L Bancroft in H Br

D alternifolia is allied to *D heterophylla* and has been considered as a mere variety of this species by various authors

It is limited to the north eastern part of Australia, though it has been observed in Thursday Island it does not occur in New Guinea

3 *Dolichandrone heterophylla* F v M, Fragm 4 (1864) 149, in obs, excl syn

Seem, Journ Bot 8 (1870) 382, F v M, Syst Cens 1 (1882) 99, Sprague in Kew Bull (1919) 304, V St Duss (1927) 935, fig 10b, 11 (2) (geogr distr) *Spathodea heterophylla* R Br, Prod (1810) 427, DC Prod 9 (1845) 207, Benth, Fl Austr 4 (1869) 538, Bailey Queensl Fl 4 (1901) 1135, Fwart & Davies, Fl North Terr p 250, Bailey Compr Cat (1909) 364, fig 344

Scrubby glabrous tree, 3.5 m high, bark rugged Leaves crowded in dense masses, mostly in whorls of 3, coriaceous, simple or pinnate, 1-3-jugate, rather varying, sometimes with 2 leaflets, leaflets oblong-lanceolate to linear, 2½-7½ cm long, simple leaves mostly lanceolate, 3½-12 cm long,

narrowed into the petiole without articulation, nerves and veins oblique, nearly parallel to the margin. Flowers white in few-flowered, short, terminal racemes 5-10 cm long, fragrant, pedicels 1-2½ cm long. Calyx 2½ cm long. Corolla-tube slender, 3½ cm long, only dilated near the apex, lobes nearly 6 mm in diameter, broadly rounded, margins undulate and crispate. Disk thick and fleshy. Capsule from 5 to more than 30 cm long, compressed when dry, valves slightly concave, false septum almost reaching the margins of the valves, seeds, including the 1 cm broad wings, 3 by ½ cm.

North Australia. Islands of the Gulf of Carpentaria, R. Brown in H Br, Henne (Benth 1 c), Victoria River, F v Mueller (Benth 1 c), Careening Bay, NW coast, A Cunningham (Benth 1 c), Roebuck Bay, NW coast, Marten (Benth 1 c), Kings Ponds, in the interior, McDouall Stuart (Benth 1 c).

Queensland. Stannary Hills, T L Bancroft, fr fl xii, 1908 in H Br, Newcastle Range, A H Blackman fr vii, 1906 in H Br.

6 DEPLANCHEA Vieill

Bull Soc Lin Norm 7 (1862) 11, F v M, Syst Cons 1 (1862) 99, ed n 1 (1889) 167, V St, Diss (1927) 906, fig 8, 9 (geogr distr), in Bull Jard Bot sér iii, 10 (1928) 218, *Diplanthera* Banks & Sol, ex R Br Prod (1810) 148, reprint 1 (1827) 304, Endl, Gen Pl (1836 40) 678, DC Prod 8 (1845) 229, Bureau in Soc Bot Fr 9 (1862) 16 Mon (1864) 51, F v M, Fragn 5 (1865) 72 214, Seem in Journ Bot 3 (1865) 93, F v M in Journ Bot 5 (1867) 212, Benth, Fl Austr 4 (1868) 540, Schoffer in Nat Tijdschr Ned Ind 31 (1870) 332, Seem in Journ Bot 8 (1870) 148, 163, Benth & Hook, Gen Pl 2 (1876) 1048 Baill, Hist Pl 10 (1891) 44, K Sch in Engl & Pr Nat Pl Fam iv, 3b (1894) 235, Ridley, Fl Mal Pen 2 (1923) 552, V St in Nova Guinea, 14 (1927) 293, Lindert, Diss (1928) 193, *Bulweria* F v M, Fragn 4 (1864) 147 *Montravetia* Montr, nomen ex Beauvillage in Ann Soc Bot Lyon 26 (1901) 89.

Trees with thick branches. Leaves large, verticillate (rarely opposite on young shoots), simple, ovate or oblong, mostly with large glands at the base above, entire, mostly yellow-tomentose as the ultimate branches and the inflorescences, sometimes glabrous. Thyrses terminal, large, mostly yellow tomentose. Flowers rather large. Calyx campanulate, coriaceous, valvate in bud, 3-lobed (posterior lobe entire, lateral lobes 2-toothed) or with 5 subequal lobes, sometimes with glands, hairy or glabrous. Corolla yellow, tubular-ventricose, subbilabiate, 5 lobed, dilated towards the throat, lobes nearly round. Stamens 4, didynamous, distinctly exserted, rarely with a fifth rudimentary one, anthers with distinctly divergent cells, reflexed in bud. Ovary subsessile, bilocular, with 2 placentas in each cell which are sometimes adnate, ovules numerous, in many rows, style exserted with a bilamellate stigma. Capsule 2-valvate, oblong or lanceolate with strongly coriaceous or even woody valves, seeds numerous, with a broad, finely membranous wing.

Species 8, distributed from the Malay Peninsula to East Australia, New Guinea, and New Caledonia, type species *Deplanchea tetraphylla* (R Br) F v M.

- 1 Leaves 4 verticillate (or on the youngest shoots rarely opposite) obovate, mostly cuneate at the base, underside with a thick dense yellow tomentum, nerves 7-9 on each side of the midrib. Rather tall tree.

1. *D. tetraphylla*.

Leaves 3-verticillate (or ? rarely opposite), rather narrow lanceolate, more or less rounded at the base, underside hirsute, never with a dense tomentum, nerves 18-19 on each side of the midrib. Rather ? small tree

2. *D. hirsuta*

1. *Deplanchea tetraphylla* (R Br) F v M, sens ampl

Syst Cens. 1 (1889) 167, V St, Diss (1927) 916 fig 8 (c, d), 9 (2) (geogr distr), *Deplanchea tetraphylla* R Br, Prod (1810) 448, reprint (1827) 304, Verm Bot Schrift III, 1 (1827) 305, Benth, Fl Austr 4 (1869) 540, Scheffer in Nat Tijdschr Ned Ind 31 (1870) 394, Ill Bot Cook's Voy, p 72, t 229, Bail Queensl Fl 4 (1901) 1137, Compr Cat (1909) 368, White in Proc Roy Soc Queensl 34 (1922) 52, White & Francis in op cit, 37 n 15 (1927) 259, V St in Nova Guinea 14 (1927) 293, *Bulweria nobilissima* F v M, Fragm 4 (1863-64) 147, *Tecomella Bulweri* F v M, Fragm 5 (1865-66) 72, 214, nomen

Big tree, stem diameter often exceeding 1 m, wood whitish, close-grained and firm, bark thick, soft and somewhat corky, the crown of the tree irregularly diffuse, often umbrella-shaped, branchlets ca 1 cm thick. Leaves short-petioled, subcoriaceous to coriaceous, crowded at the ends of the branchlets, 4 verticillate (rarely on young twigs opposite), ovate, obtuse, or elliptical obovate, or oblong, cuneate at the base, rather abruptly contracted into the petiole though never cordate, glabrous above, slightly scabrous, or pubescent on the main nerves, on the underside covered with a thick soft yellow tomentum, often with a golden or bronze hue and consisting of single or clustered but scarcely stellate hairs, the elder ones 30-60 by 30 cm or broader, mostly (those of flowering specimens) 15-23 by 8-14 cm, midrib at the base as thick as the petiole, strongly prominent, basal part above with 0-7, mostly 2-3 large brown cup-shaped glands, primary nerves 7-9, erect-patent, all making a sharp angle with the midrib, prominent as the wide reticulations, all nerves sunken in above, petiole stout, 3-5 by 0-25-0-4 cm, thickened at the base and spanning round one-fourth of the girth of the branch, yellow-tomentose, leaf scars cordate, 6-7 mm broad. Thyrses a dense layer of corymbose nature, terminal on the branchlets, 15-20 cm in diameter, yellow-tomentose, sometimes nearly glabrous, peduncle stout, 9-12 by 0-8 cm or much shorter, the upper half densely branched, often with some reduced leaves at the base, primary axis horizontal, whorled, terete, 4-6 cm long, 2-3 times forked with a flower in each fork, sometimes 3-flowered, bracts linear, 5-8 mm long, pedicels of the lateral flowers 1½-2 cm, those of the terminal ones 1 cm long. Calyx coriaceous, 13 mm long, articulate on a short hypanthium, broadly campanulate, yellow-pubescent when young, tube 7 by 8 mm at the throat, 3-lobed, the posterior lobe recurved, the lateral ones erect split down to 3-4 mm from the tip, all 10 by 9 mm, ovate-triangular, acute, somewhat carinate and indistinctly penicillate at the tip. Corolla yellow, tube campanulate, slightly exceeding the calyx, curved, limb bilabiate, 2½ cm long (lob incl), glabrous outside, 5-lobed, lobes as long as the tube, ovate orbicular, margin ciliate. Stamens and style exceeding the corolla-tube by 2½ cm or more, divergent and curved towards the peduncle as the style. Stamens didynamous, inserted near the base of the corolla, filaments 3½ and 4 cm long, slightly pilose near the base, anthers with divaricate cells, reflexed in bud. Disk fleshy, flat. Ovary oblong, 4 mm long, ovules in 5-6 rows on 2 distinct placentas

in each cell Capsule $5\frac{7}{8}$ cm long with woody, hard valves which are smooth inside with a longitudinal line where the thick somewhat fleshy dissepiment was attached, seeds flat broad, but exceedingly fine membranously winged.

Distribution New Guinea and Queensland

Queensland Boar Pocket, J F Bailey in H Br, fl 16 vi, 1899, without locality in H Br, Thursday Island, F M Bailey 85 in H Br, fol vi, 1897, Jahari in H B, fl 19, v, 1901, Cairns, C T White in H Br, Cardwell, F M Bailey in H Br, J L Tardent in H Br, fl fr xi, 1926, Temple Bay, Cape York Peninsula, J E Young in H Br, fl vii, 1923, tree with umbrella shaped top up to 20 ft, Cape York, MacGillivray, Daemel (Benth 1c), Musgrave Telegr Station, Cape York Peninsula, T Barclay Miller in H Br, between Ingham and Townsville, N A R Pollock in H Br, Rookingham Bay, F von Mueller in H B, H P, H U sub n 001067, 001066, Dallachy 1169 in H S, Endeavour River, Banks and Solander (Benth 1c), Brisbane, off a plant cultivated at Bowen Park and brought from Cardwell, F M Bailey in H Br

2. *Deplanchea hirsuta* (Bail) V St, Dias (1927) 920, fig 9 (5) (geogr distr)

Diplanthera hirsuta Bail in Departm Agric Bot Bull 14 (1896) 11, Queensl Fl 4 (1901) 1137, Compr Cat (1900) 368

Small tree, branchlets subterete and densely hirsute Leaves in whorls of 3, rarely opposite on young shoots, acute to broadly truncate at the apex, up to 50 cm in length with a breadth of 17 cm about the centre, margins repand, crenulate or deeply and very irregularly toothed, base cordate and much undulate, petiole $1\frac{1}{2}$ -4 cm, hirsute, later on nearly glabrous, nerves rather irregular, not parallel, 18-10 on each side of the midrib, distinctly prominent as the gross and fine reticulations Calyx $1\frac{1}{2}$ cm long, campanulate, coriaceous, inside with scale like glands, 3 lobed, 2 side lobes emarginate Corolla ringent, yellow, $2\frac{1}{2}$ cm long, spreading to $3\frac{1}{2}$ cm wide, lobes blunt, longer than the tube Stamens 4, exceeding the corolla by 3-7 cm, style about the length of the stamens stigmatic lobes ovate apiculate Capsule unknown

Queensland Cairns, Stony Creek, L J Nugent in H Br, a shoot and loose flowers, Thursday Island, E Cowley 56 in H Br, large leaf (shoot cited by Bailey lost?)

Notwithstanding the imperfect materials cited I am convinced that it is a distinct species, though it must be studied further, especially as to its distribution The 3 lobed calyx and the short corolla tube show its affinities with *D tetraphylla*

EXCLUDED SPECIES

***Pandorea leptophylla* (Bl) Boer**

This species is erroneously referred by me to the Queensland flora in Bull Jard Bot Buit sér iii, 10 (1928) 201 The two specimens mentioned in that paper are youth forms of *Pandorea pandorana*, as was found out by Mr C T. White from Queensland specimens, and by myself when studying the cultivated species in the Botanic Gardens at Buitenzorg.

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Revisional Notes on the Tribe Brachyrrhopalini (Robber Flies), with Remarks on Habits and Mimicry.

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(Read before the Royal Society of Queensland, 21th June, 1929)

THE genus *Brachyrrhopala* was proposed for a single species in 1847, namely *B. ruficornis* Macquart, the leading diagnosis being the short clubbed character of the abdomen, this narrowing to the apex of the second segment, widening from there and being rounded at the apex of the abdomen

Roder recognised the genus and widened it by placing thereunder other but unrelated forms with clubbed abdomen. He described *B. victorie* and *B. maculata*, also he placed *Dasypogon maculineris* Macquart there

Ricardo followed Roder's arrangement, describing *B. fulvus*, but suggested *Codula quadricinctus* Bigot was identical. She also included *Codula fenestrata* Macquart, referring *B. victorie* as a synonym of it. In addition she placed *Dasypogon limbipennis* Macquart under the genus, but erroneously regarded *Dasypogon maculineris* Macquart as a synonym of it. She further confused the genus by including *Dasypogon nitidus* Macquart

White subsequently followed Ricardo, adding *Brachyrrhopala bella*. Up to this time the only criticism of the position was given by White — "*B. fenestrata* differs so much from *B. nitidus* and *B. limbipennis* in the shape of the abdomen and much shorter wings that it might well be made the type of a new genus. It seems to be nearly allied to the genus *Codula*, but differs in having a curved terminal spine on the anterior tibiae, this character, however, in some specimens is difficult to make out, and I am somewhat doubtful of its value as a generic character" (White 1916, p 158)

White did not recognise the typical form of *Brachyrrhopala*, and had he done so he most certainly would have reversed his suggestion so as to place *B. nitidus* and *B. limbipennis* elsewhere. White's implied suggestion that *Codula* and *Brachyrrhopala* should be treated as one genus has also been suggested to me from another source, and it is one that I think would commend itself to many Dipterists, only there are supplementary characters subsequently given for the former genus that would prohibit this arrangement

In the meanwhile *Codula limbipennis* remained uncertainly recognised, but its identity is now fairly well assured, so relationship between these genera can be cleared up as well as the identity of the species described under them. The disposition of species hitherto placed under these genera is as follows —

Codula limbipennis Macquart is the genotype of *Codula* by original designation

Codula respiformis Thomson is a synonym of *C. limbipennis*

Brachyrrhopala ruficornis Macquart is the genotype of *Brachyrrhopala* by original designation

Codula fenestrata Macquart belongs to *Brachyrrhopala*

Brachyrrhopala tutoria Roder is regarded as a synonym of *B. fenestrata*

Codula quadricinctus Bigot is a *Brachyrrhopala*

Brachyrrhopala fulva Ricardo is a synonym of *B. quadricinctus*

Recently I added *Cabasa* Walker as a synonym of *Brachyrrhopala*, thus bringing in four further specific names representing one valid species *Dasyopogon pulchella* Macquart

Dasyopogon maculinervis Macquart is an *Erythropogon* White

Dasyopogon limbipennis Macquart is another *Erythropogon*

Dasyopogon nitidus Macquart is a *Nicosiopogon*

Brachyrrhopala bella White is near *Saropogon*

Brachyrrhopala maculata Roder has not been recognised, but judging from the description is certainly not of that genus compare with the descriptions of *Dasyopogon scirpus* and *D. fenestans* Walker, both placed by Ricardo in *Saropogon*, but more certainly belonging to *Nicosiopogon*

The genus *Cabasa* may be ranked as of subgeneric value on certain characters given in the key below. Other generic relationships in this tribe are clearly indicated in literature and need no special comment here

Key to the Genera of the Brachyrrhopalini

- | | |
|---|---|
| <p>1 Thorax provided with a pair of lateral spines, one placed on each side immediately above the insertion of the wings. Moustache limited to the oral margin or practically so. Female with the ovipositor strongly compressed</p> <p>Thorax without such spines, gibbous. Moustache usually extending above the oral margin, being represented there by soft hairs on the lower part of the face. Female with ovipositor not of the compressed type</p> <p>2 Antennæ provided with four readily discernible segments and a minute apical spine</p> <p>Antennæ with only three segments and a spine, at most the fourth segment is vestigial, the line of demarcation between it and the third being just visible</p> | <p>2</p> <p><i>Brachyrrhopala</i> 4</p> <p><i>Chrysoopogon</i> Roder</p> <p>3</p> |
|---|---|

- 3 Spine at apex of the third segment of antennae large and conical. Abdomen with seven segments always visible. Tibial spur present. *Opiocostellus* White
- Spine on third segment of antennae minute. Abdomen with only six visible segments. Tibial spur absent. Thorax rather gibbous. *Codula* Macquart
- 4 Abdomen narrowest at the base of the second segment and always with eight visible segments. Moustache confined to the oral margin, or at most with a few hairs immediately above it. Black species with a highly gibbous bright red thorax. Subgenus *Cabasa* Walker
- Abdomen narrowest at the apex of the second segment. Face with many soft hairs extending well above the bristly ones on the oral margin. Thorax usually black and less gibbous. Subgenus *Brachyrhopala* Macquart

Genus *CODULA* Macquart

Macquart 1849, 70, Ricardo 1912, 149, Hardy 1921, 292

This genus is sufficiently well diagnosed for recognition in the key given above, but it may be here added that the second segment of the abdomen is uniformly wide throughout and somewhat stouter than that in the genus *Brachyrhopala*. I have not detected the seventh segment of the abdomen on the female when the ovipositor is exerted, and so suggest that this segment may ultimately be found reduced and absorbed by the very compressed ovipositor. Though resembling *Brachyrhopala* in many respects, this genus shows in most of its characters that the affinities are nearer to *Chrysopogon*.

Codula limbipennis Macquart

Asilus conopsoides Fabricius 1775, p. 795, '*Dioclea conopsoides* Fabricius 1805, 151, Kertész Cat. Dipt. 1909, 106 (which see for full references under the names)

Codula limbipennis Macquart 1849, 70, Pl. 7, fig. 1, Ricardo 1912, 149

Codula veriformis Thomson 1869, 464, Ricardo 1912, 150, Nicholson 1927, Pl. 1, fig. 2

Synonymy—Although there are many references to *Asilus* (*Dioclea*) *conopsoides* Fab., at most all are copies of the original description. None of the subsequent authors seem to have recognised the species, and Ricardo proposed to "expunge the name" as she considered it was impossible to ascertain the genus. The original description, however, fits the present species remarkably well, and the form is sufficiently *Conops*-like to be worthy of the name. It is certainly common enough to have been taken by Banks, and the only criticism I have to offer is that I have no record of its occurrence during the month when Banks visited these shores.

There can be little doubt concerning the remainder of the above synonymy and I have seen a sufficiently long series to be reasonably convinced that the various descriptions can apply to but one species, whilst Macquart's description and Ricardo's notes on the type conform to it.

Description.—The female has not hitherto been described, it conforms to the male in characters. The antennæ are not quite as in the *Brachyrrhopala*, for the fourth segment is still traceable, and they do not conform to those found in the genus *Chrysopogon*.

Habitat.—Queensland, New South Wales, and probably Victoria. The allotype female and a series of paratype females are in the Queensland Museum, other paratypes are in the collection of Mr J. Mann.

Genus BRACHYRRHOPALA Macquart

Macquart 1847, 36, Ricardo 1912, 486, White 1916, 156, and 1918, 74, Hardy 1921, 292, and 1926, 307, fig 1

Cabasa Walker 1850, 100, Ricardo 1912, 479, White 1916, 155, Hardy 1921, 291

The genus *Cabasa* was previously placed as a synonym by me, and although some differences have since been discovered that would separate the form from *Brachyrrhopala*, these do not seem to be more than of subgeneric value. Three forms retained here as being of specific value may ultimately prove to be but one widely varying species, or two at the most. *B. ruficornis*, *B. fenestrata*, and *B. quadricincta* appear to be identical in structure, but there is another species as yet to be described that has the antennæ twice as long as on these, the legs are unicolorous and the wings lightly suffused with brown throughout. This undescribed form suggests that structures are not so consistent as hitherto thought to be, but that structures are not to be entirely relied upon as a criterion for species in this genus is seen by the new form here described. In this case we have a quite distinctive species that seems to conform to the *ruficornis* group in all its general structures. On this account I am leaving the status of the species in the *ruficornis* group unaltered, making the reservation that the status of two species is not quite satisfactory.

There is a new genus that is a member of the *Saropogonini*, but has a superficial appearance of the genus *Brachyrrhopala*. To this new genus I believe *B. bella* White comes. It is noteworthy in so far as a true moustache is not formed, instead it has long, soft, scattered hairs, disposed very much in the same way as the similar hairs of the thorax, none occurring on the oral margin. It is some years now since I last examined White's species and I made no detailed notes of that form at the time, but its description does not conform to the species before me.

Key to the species of the genus *Brachyrrhopala*

- 1 A black species with a strongly gibbous red thorax, containing black markings. Wings varying from completely black to semi hyaline. Abdomen varying slightly, either completely black, or metallic blue black, or else with a white spot on the second segment, the sclerites are rather soft.

pulchella Macquart

Black, black and red, or black and yellow species, usually with some of the abdominal segments margined with red or yellow. Thorax never vivid red, at most obscurely red, less gibbous. Abdomen with hard rigid sclerites.

2. A black species with the dorsal area of the abdominal segments 4 to 6 completely reddish yellow (vivid red when alive). Wings almost completely brown. Antennae, all knees, and posterior tarsi reddish yellow, the intermediate tibiae may also be reddish.

semirufa n. sp.

Wings only partly suffused with brown, all legs partly red, abdomen banded with black and yellow or red.

3

3. Yellow on abdomen restricted to a narrow band at the apex of the second, third, and sixth segments. Wings infuscated across the base of the median cell, this marking runs to the base along the radial and cubital veins.

ruficornis Macquart

Markings on abdomen not so limited.

4

4. Yellow on abdomen restricted to a band at the apex of the second, third, fifth, and sixth segments. Wings infuscated over most of the area, but leaving hyaline areas, conspicuously so in the basal and median cells. Face entirely black (or whitish at sides according to other authors).

fenestratus Macquart

Apex of most abdominal segments yellow, or this colour may extend over the whole of certain segments, and at least the second abdominal segment is mainly yellow. Wing markings vary from approaching that of *fenestratus* to that of *ruficornis*. Face yellow at sides.

quadrimaculatus Bigot

Brachyrrhopala pulchella Macquart

Dasygogon pulchella Macquart 1846, 62, Pl. 7, fig. 9.

Cabasa pulchella Hardy 1920, 185 (which see for synonymy and references).

Brachyrrhopala pulchella Hardy 1926, 307, 1927, 394, Nicholson 1927, Pl. 1, fig. 35.

There would appear to be one very variable species incorporated in the synonymy, and no published characters are found sufficient to distinguish lines of demarcation between these forms when long series are examined. A well-known but unpublished variation is described under a new name in the Gibbons manuscript and labelled in his collection, it has a white mark on the second segment of the abdomen. Even this character varies, the mark ranging from a small dot to occupying practically the whole of the dorsal area of the second segment, on old specimens this spot becomes obscure and difficult to detect. The species ranges from Tasmania to Queensland, but I have never seen a specimen from the former State having that white mark.

Brachyrrhopala ruficornis Macquart

Macquart 1847, 36, Pl. 1, fig. 7, Walker 1854, 494, Roder 1883, 273, Ricardo 1912, 586, White 1916, 158, Hardy 1918, 66, and 1927, 394 (nec Froggatt 1907).

The female of this species was described from Tasmania, and the one specimen before me, a male, agrees remarkably well with the description. The sex was queried by Macquart, but it was undoubtedly given correctly as the male organs are always visible on specimens of this genus. The form was first rediscovered in the Lattler collection in 1917, and the one before me is the only other specimen I have seen.

It differs from Tasmanian specimens of *fenestrata* chiefly in the wing marks, but also in the colour on the apical margin of the fifth abdominal segment. No intermediate forms have been seen from that State. Froggatt's record from Queensland is referable to *B. quadricinctus* Bigot, if indeed these forms are distinct.

Habitat—Tasmania Hobart, January, 1924, 1 male allotype

***Brachyrrhopala fenestrata* Macquart**

Codula fenestrata Macquart 1849, 79, Pl. 7, fig. 2

Brachyrrhopala fenestrata Ricardo 1912, 596, White 1916, 157

Brachyrrhopala victoriana Rodet 1892, 241

Originally described as from Tasmania, there is some doubt concerning the correctness of this type locality. My identification is based entirely on Tasmanian material, following White, but Ricardo recognised it from Victoria, and her redescription of the type certainly conforms to Tasmanian material more than to any known to me from the mainland. Many mainland specimens of *Asilidae*, especially Queensland ones, are much lighter in colour than representatives of the same species from Tasmania, and Mr. H. Hacker, of the Queensland Museum, informs me he has noted similar lighter tones apply to certain Homoptera. Possibly in Victoria specimens are to be found that will complete the series of variations between the present species and *B. quadricinctus*.

Habitat—Tasmania Hobart, 24th January 1915, Dunally, 21st February, 1918, Wynyard, February 1924. All three are females. The Wynyard specimen was one of several seen resting high up telegraph poles, and was difficult to catch.

***Brachyrrhopala quadricincta* Bigot**

Dasypogon nigrinus Macquart 1849, 66, Ricardo 1912, 351

Codula quadricincta Bigot 1878, 442, Ricardo 1912, 588

Brachyrrhopala fulva Ricardo 1912, 588, Hardy 1927, 394

Brachyrrhopala ruficornis Froggatt 1907, 300 (nec Macquart)

Brachyrrhopala fenestrata Nicholson 1927, text fig. 3A and Pl. 1, fig. 24

The type of *Dasypogon nigrinus* Macquart is a male in the Paris Museum, and it was examined by Ricardo, who states, "but the short antennae seem to preclude it from belonging to the genus *Brachyrrhopala* or *Codula*." Also she referred to the third segment of the antennae as being "conical, about as long as the first two together." The length at least, as given by her in this manner, suggests *Brachyrrhopala* rather than otherwise. Fifth and sixth segments with testaceous margins, and the seventh testaceous, certainly conforms to the abdomen in this genus, as also other characters mentioned. The type locality is Tasmania, but as the description occurred in the fourth supplement probably Sydney is the true locality. I think the species may refer to the same as that known on the mainland as *B. fenestrata*, and not necessarily the same as that known under the name from Tasmania.

There can be little doubt concerning the correctness of the other references given above, part of which was suggested by Ricardo. The descriptions are referable to a very variable Queensland species that has the second abdominal segment entirely yellow or almost so. Even when very dark, and having the wing pattern similar to that of *B. fenestrata*, this is the case. The question now arises as to whether New South Wales and Victorian specimens named *fenestrata* in collections are not *quadricincta* Bigot, also it is pertinent to remark that if the colour of the second abdominal segment is not consistent, as it appears to be from a series of Queensland specimens, then there are no known characters to distinguish between *fenestrata* and *quadricincta* as here recognised. As far as I know them at present, geographical distribution, allied with colour characters, suggests that the two may hold good in their specific status.

Habitat—Queensland Brisbane and Stradbroke Island, September to February. New South Wales Richmond River, October, 1 male.

Brachyrrhopala semirufa n. sp.

A very distinct species that can scarcely be confused with those referred to above. The head, thorax, anterior and intermediate femora except the knees, posterior femora except apex, the first two abdominal segments above and the whole area below, are all black. The remaining segments of the abdomen, when alive, are vivid red above but on dried specimens fade to reddish yellow. The apices of all femora are reddish, as also the posterior tibiae and tarsi. On one specimen the intermediate tibiae are also reddish. As usual with species of this genus, the antennae are reddish and the face is covered with yellow tomentum bordering the eyes, leaving a shining black central stripe. The wings are almost entirely suffused with brown, more anteriorly so along the veins, the membrane of the wing tends to become hyaline only near the posterior margin.

Length—12 mm.

Habitat—Queensland Brisbane, the holotype, a male, September 1928, two paratype males, Brisbane and Stradbroke Island, December 1912. The two last are in the Queensland Museum and were taken by Mr H. Hacker.

Genus CHRYSOPOGON Roder

Roder 1881, 213, 1892, 234, Ricardo 1912, 481, White 1917, 72. Hardy 1921, 288, Malloch 1928, 300.

This genus would seem to come between *Opseostlengis* and *Codula* in regard to several of its characters. The spine at the apex of the antennae is minute as in *Codula*, not large as in *Opseostlengis*, and the abdomen has seven visible segments as on *Opseostlengis*, whereas *Codula* has six. Most of the smaller forms have the abdomen widening from the base to the apex of the fourth segment, in *Opseostlengis* it widens to the apex of the fifth. However, one species, *C. mullers*, narrows from the base to the apex of the second segment (which is a

character of *Brachyrrhopala*), after which it widens out, but on the male of *C. mulleri* it becomes practically parallel from this point. It is not at all certain if the coalescence of M_1 and R_5 near the wing margin will be maintained entirely in the venation, but in the event of this failing the large size of the three species classed as having the character will readily group those forms *C. crabroniformis* and *C. splendidissima* have been regarded by several entomologists as mimic forms of certain large wasps.

Key to the species of Chrysopogon

- 1 Wings with M_1 and R_5 coalescing near the wing margin
Very large black and yellow species 2
Wings with M_1 and R_5 separated at the wing margin
Abdomen widening from the base to the apex of the fourth segment. Medium and small sized species 4
- 2 Abdomen narrowing from the base to the apex of the second segment, more or less widening from thence to the apex of the fourth segment. Moustache with one row of bristly hairs *mulleri* Roder
Abdomen widening from the base to the apex of the third segment. Moustache composed of one row of bristly hairs, rarely with hair above these 3
- 3 Abdomen with segments 3 and 4 entirely black *crabroniformis* Roder
Abdomen with the third segment only partly marked with black, and the fourth above without black or almost so *splendidissima* Ricardo
- 4 Moustache bushy along the oral margin. Abdomen with the first, base of second, third, and base of fourth segments black, elsewhere yellow *albopunctatus* Macquart
Moustache confined to one row of hair 5
- 5 Abdomen banded with gold at the apex of the first to fifth segments, the base of the sixth also golden *fasciatus* Ricardo
Abdomen never with gold 6
- 6 Abdomen entirely black, except some silvery lateral spots and narrow bands at incisions of segments may be present. Legs entirely black *punctatus* Ricardo
Abdomen never entirely black, or if so the legs are of a lighter colour 7
- 7 Abdomen with a large part of the dorsal surface black, but laterally, the apex of the fifth, the whole of the following segments, and the whole abdominal area below is reddish brown 8
Abdomen largely black, but usually from the second to sixth segments are reddish brown at apex, if the abdomen becomes entirely black, the reddish brown legs will distinguish the species *queenslandi* Ricardo
- 8 Legs reddish brown *rufus* White
Legs entirely black *nigricans* White.

***Chrysopogon mulleri* Roder**

Roder 1892, 243, Ricardo 1912, 483

This species was described from Victoria, from which State specimens were seen by me some years ago. The specimens now before me were kindly lent by Mr. A. J. Nicholson, who took them in New South Wales, the male is from Capertee, and the female from Ilford, both dated 29th December, 1923. There is often a strong tendency for the abdomen to become greasy and the colour markings thus obscured.

***Chrysopogon crabroniformis* Roder**

Roder 1881, 213, Ricardo 1912, 481 Nicholson 1927, p. 47, Pl. II, fig. 3

This common Queensland species is apparently confined to inland districts. Those dated indicate the month of February is the time of their occurrence on the wing.

***Chrysopogon splendidissimus* Ricardo**

Ricardo 1912, 485

Originally this was described as from Western Australia, so the form would appear to have a very wide range. Specimens before me are from Albion, New South Wales, 6-1-29 (F. E. Wilson), and Chinchilla, Queensland (A. P. Dodd), both being females.

***Chrysopogon albopunctatus* Macquart**

Dasyopogon albopunctatus Macquart 1846, 193, Walker 1854, 578

Laparus albopunctatus Schiner 1867, 769

Neolaparus albopunctatus Kertész 1909, 119

Chrysopogon albopunctatus Ricardo 1912, 482, Dakin and Fordham 1922, 524

Dasyopogon spinthor Walker 1849, 337, 1854, 479

This was described by Macquart as from New South Wales, but it seems to be known only from Western Australia, where it is common and widely distributed. One specimen before me has a small species of *Apocera* as prey.

***Chrysopogon punctatus* Ricardo**

Ricardo 1912, 484

A pair in Mr. J. Mann's collection, captured in Brisbane during the months of December and January, are the only specimens I have seen. There is no mistaking this all-black form, which is not known outside Queensland. A female from Goondiwindi is allied, but has abundant hair above the moustache (December 1927, G. R. Bassingthwaite).

***Chrysopogon fasciatus* Ricardo**

Ricardo 1912, 483, ?*Chrysopogon* sp. near *fasciatus* Nicholson 1927, Pl. I, fig. 21

There are two species known to me that have the abdomen conspicuously marked with gold, in one the gold bands are interrupted, in the present case they are continuous across the abdomen. One female, Bunya Mountains, 3,000 ft., 9-1-26 (Dr. A. J. Turner).

***Chrysopogon rufulus* White**

White 1914, 268

Five male specimens are before me, all from Perth, Western Australia, one of these is the type which White recorded as being a female, but he was misled by some foreign substance which adhered to the hypopygium and is now removed, showing the true nature of that organ

***Chrysopogon nigricans* White**

White 1914, 268

Two specimens, both females, are before me. White had access to these and the five '*rufulus*' referred to above, but he made no reference to other than the holotypes. The two forms are closely allied and the sexes are consistent in each case, thus suggesting they may be but the sexes of one dimorphic species, especially as all are from Perth, Western Australia

***Chrysopogon queenslandi* Ricardo**

Ricardo 1912, 184

There are two specimens in Mr J Mann's collection from Kuranda, December 1927 (A P Dodd), and a darker specimen in my own collection from Coen River (W D Dodd). Specimens originally described were also from Queensland, but Ricardo also reported a specimen from Western Australia which he considered to be the same species

***Chrysopogon pallidipennis* White**

White 1918, 72

The unique type was described from Sydney, New South Wales, and according to its published characters it would run out in the above key to '*C. queenslandi*'. White gives the colour as yellow, and there is a specimen before me from Southern Queensland that approximates White's description, this having yellow margins on the fifth and sixth abdominal segments, but the legs are coloured as in '*C. queenslandi*', missing only the fuscous stains on the femora. It is possible that White described a pale specimen of '*C. queenslandi*', and that the one before me is an intermediate variety. There is a still brighter form from Cairns, represented by five specimens in Mr J Mann's collection

***Chrysopogon rubripennis* White**

White 1918, 73

Not seen by me and was described from a unique Victorian specimen, it should be easily recognised by the claret-red thorax

Genus OPSEOSTLENGIS White

White 1914, 269, Hardy 1921, 288

I have already given the generic characters of this genus, but attention must be drawn to the moustache which White states arises from the middle of the face, it is situated on the oral margin as in *Chrysopogon*, &c

Opseostlengis insignis White

White 1916, 269

The unique type is a male, not female as White states, it is difficult to understand how this error arose, considering the claspers are clearly defined.

OBSERVATIONS OF SOME HABITS OF AND MIMICRY AMONGST ROBBER-FLIES.

These notes do not aim at crediting or discrediting any views expressed in favour of or against the theory of mimicry as far as it affects robber-flies. They reflect upon some aspects of the case that rather support the idea that mimicry may occur in the family in contradistinction to the views Melin (1923) expressed, which views uncompromisingly denounce the principles from several aspects. On reading Melin's remarks about robber-flies, one is rather strongly led to the view that these insects are robust and active enough to escape danger without having to resort to deceptive measures for their own protection. But this is not invariably the case, for I have caught many specimens, especially species of *Cerdistus*, by placing a tube over them whilst they were resting between their intermittent periods of hawking. A still weaker type is represented by species of *Leptogaster* which would appear to have very little protection against any insectivorous bird that might come their way, whilst the slow flight and the wary nature of their movements preclude them becoming seriously tangled in spiders' webs.

Where other invertebrates are concerned, robber-flies are the most skilled of their kind. I have not seen one preyed upon in Australia, on the other hand predaceous of most kinds succumb to them, including dragon-flies and spiders. Nor have I seen birds attempt to catch them, though I have watched birds pounce upon Bombyliidae on the wing, these flies being more active in flight. Nevertheless there is one record of a bird eating a robber-fly, and several cases of insects, such as Mantis, bees, and wasps, that have gained the mastery when robber flies have attacked them, these being noted in other countries. Many would seem to be caught in spiders' webs, but in Australia, although I have seen many arrested in this manner, they invariably break free again, if indeed they do not break right through in their headlong flight.

Nicholson (1927) has drawn attention to resemblances between certain robber-flies and wasps, but his work treats only with the principles of mimicry, and does not incorporate data of consequence to support the view that mimicry amongst robber-flies is indisputable.

There are, of course, varying degrees in mimicry, and no robber-fly seen by me in the field has had the perfection reached by certain Syrphidae, especially *Ceriodes subarmata*, which is well-nigh indistinguishable from a wasp in colouration, shape, and deportment, and moreover has advanced so far along this line as to fold its wings longitudinally as an Eumenid wasp, for which it is readily mistaken.

There would be no reason to doubt the occurrence of mimicry amongst robber-flies if such a case should be found where a mimic and its model were to be found to have identical colouration and deportment, so the question arises as to how far mimicry amongst robber-flies has gone, if at all

A reasonable chance of attaining information is to ascertain if the mimic forms have adapted habits away from the normal of the family, tribe, or genus to which they belong, and if by so doing they have reasonably added to their chance of survival. It is to indicate possibilities along this line that the present note is written, and there is no intention to show here that mimicry is resorted to for the protective measures it may yield

The genus *Leptogaster* is mainly found hunting and resting amongst grasses and reeds, not infrequently also around dead twigs on trees, especially in fairly dense bush where grassy undergrowth is not abundant. These flies rest on grass-stems and twigs alike, with their bodies held horizontally, and, when going into a state of coma, all their tarsi are bunched to grip their support immediately adjacent to the face. On twigs they invariably take up their position at the tip of the twig, becoming in this manner a continuation of the twig, having the appearance in this case of assuming a protective attitude of mimicry. On grasses and reeds no such state of mimicry can be expected, and, on the two or three times I have found them there in the state of coma, their colours did not particularly become absorbed by their surroundings.

The *Saropogonini* are all ground-frequenting at the time of oviposition. Many of them seem to be entirely ground-frequenting, in a few cases the male frequents flowers, rarely so the female, whilst in one case, *Erethropogon*, the species is abundant at flowers, and both sexes are to be taken in numbers there.

Erethropogon limbipennis is one of the mimic forms mentioned by Nicholson, and on account of its somewhat unusual habits is deserving of deeper study, both in structure and behaviour. So far, unlike the habits of other flower-frequenters, I have never seen the species with prey. Nicholson refers to its wasp-like nature as being not unlike *Polistes*, but from my own experience I have found in its general activities it resembles the Cerambycid beetle *Hesthesis ? cinquulata* with which it occurs. One would never suspect any real resemblance by comparing specimens side by side, so the similarity depends entirely upon their actions. It is possible that these insects have a common model that was missing during my observations.

Two or three species of *Saropogon* also frequent flowers, and, like *Erethropogon limbipennis*, face the flowers, whereas *Thereutria* and other flower-frequenters seem to alight upon flowering shrubs and take up the attitude of awaiting prey, facing away from the flowers. *Saropogon* spp. are not infrequently taken with prey, whilst *Thereutria* is a persistent hawk, taking restless intermittent flights.

Another species of this tribe was mentioned amongst mimics by Nicholson, namely *Neosaropogon princeps*, a rather large yellow and black form with a somewhat clubbed abdomen, more especially clubbed on the female. It seems to be entirely ground and low-shrub frequenting, and were it not for the fact that the abdomen is clubbed there would be no real resemblance to the Hymenoptera. In all probability the name covers a complex of species in collections, and therefore general remarks may not have any particular specific significance. I have had no difficulty in recognising its nature in the field, it was recognised as an Asilid because it acted like an Asilid, not like a wasp.

The *Phellina* apparently, and the *Laphria* definitely, are mainly tree-frequenters, the *Atomosini* are ground-frequenting and as far as I have met with them they are entirely confined to the bush, where *Cryptopogon* also occurs, the latter belongs to a tribe that is as yet unnamed, but another genus belonging to it, *Chinopogon*, contains a species that frequents sand dunes on the coast and its colour tones into its surroundings in a remarkably unnoticeable way, sharing in this feature the peculiarity of *Tabanus rusticus* Walker, *Platycarenum quinquevittata* Macquart, and certain other Diptera that also occur on coastal sand-dunes.

The *Brachyrrhopalini* have mixed habits, but owing to their general scarcity any definite information is not easy to acquire. *Codula* is said to frequent tree-trunks, and *Brachyrrhopala* is not uncommonly seen on shrubs, in one case on telegraph poles, one specimen in a state of coma was found on the upper side of a leaf of a persimmon tree, looking very like a Syrphid fly, nevertheless it was not wasp-like. In activity and habits they cannot be taken for anything but a robber fly. The new species described above, *B. semirufa*, is superficially like the *Conops* sp. illustrated by Nicholson on Plate 1, fig. 9, the brightness of the red, when living, being as there given, thus bringing this species well within those types regarded as mimic forms. The genus *Chrysopogon* is recorded as ground-frequenting, but it is not certain if this habit is uniformly found throughout the genus. Nicholson remarks that *Chrysopogon crabroniformis* appears to have habits identical with *Neosaropogon princeps*, as the two species belong to different tribes, this observation may be very significant. Details of habits are wanted for the species, as several entomologists have drawn attention to its wasp-like nature in the field, and like *Erethropogon* it seems to have habits rather unusual for its type.

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A Contribution to the Chemistry of the Oily Exudate of the Wood of *Pentaspadon motleyi*.

By THOMAS GILBERT HENRY JONES, D Sc, A A C I, and F B SMITH,
B Sc, F I C

(Read before the Royal Society of Queensland, 24th June, 1929)

In 1924 Mr C E Lane-Poole, Commonwealth Forest Officer, on his return from New Guinea brought a sample of the oily exudate from the wood of a tree, subsequently described by him in the publication "The Forest Resources of the Territories of Papua and New Guinea," p 109, under the botanical name of "(near) *Pentaspadon motleyi*."

The identification of the tree as *Pentaspadon motleyi* must be regarded as provisional only, owing to the difficulty experienced by Mr Lane-Poole in obtaining complete specimens, the fruit being unprocurable. Mr C T White, Government Botanist, in conjunction with Mr W D Francis, who undertook the examination of the specimens, forwarded material to the Director of the Royal Botanic Gardens, Kew, England, for comparison with known specimens, the result being the provisional classification adopted.

Pentaspadon motleyi, with which the Papuan tree is thus provisionally identified, is indigenous to North Borneo, but the authors have been as yet unable to obtain authentic information regarding it. It is, however, hoped to obtain specimens from North Borneo for the purpose of investigation.

Pentaspadon officinalis is a better-known tree and its wood also exudes an oil. This tree is known to the Malay population of Perak as the source of "Minyak pelong," a dark-brown viscid oil which is held in great repute for skin diseases. This oil is stated by E M Holmes¹ to be of the consistency of liquid storax and to possess comparatively little odour. Efforts are being made to obtain a sample of this oil for examination.

Microscopic examination of the wood of *Pentaspadon motleyi* (Papua) was carried out by Mr W D Francis in 1925, and the following report supplied to the authors —

"The vessels are single and scattered, or less frequently arranged in radial rows of 2-3, they measure 15-04 mm in diameter and frequently contain tyloses. The wood fibres are septate and attain a diameter of 02 mm. The rays are mostly heterogeneous and vary from 5 to 2 mm in height and 09-015 mm in breadth. The larger rays contain horizontal resin canals. Crystals are present in some of the cells of the rays.

¹ Journal and Transactions of the Pharmaceutical Society of London, vol III, p 369.

The oil-like substance apparently exudes from the wood to a slight extent after it is dressed, as small patches of it appear on the planed longitudinal faces of the sample forwarded by Mr Lane-Poole. The oil-like substance appeared in the sections of the wood as a brownish black deposit situated in the lumina of some of the fibres and in some of the cells of the rays. In transverse sections of the wood the brownish black deposit in the fibres was disposed in small patches consisting of 25 or fewer cells, sometimes it was seen in isolated fibres. In most cases the brownish black deposit dissolved in a solution of sodium hydroxide."

At the request of Mr Lane-Poole, we commenced a chemical examination of the exudate on receipt of samples, and a preliminary report submitted to him was published in the "Forest Resources," p 109.

The report may be quoted here —

"The oil consists almost exclusively of acid substances, molecular weight about 400. These appear to be liquids of iodine absorption values of about 280. The acids form soaps with sodium hydroxide solution and are evidently of the nature of higher unsaturated acids. The oil does not contain any glyceride or esters and is somewhat of remarkable nature in being exclusively acid in character. Further investigation will be continued along the lines of isolation and identification of the individual acids (if more than one is present as seems likely)."

Subsequent to this preliminary examination a more detailed investigation was undertaken, but the supplies of oil available proved inadequate for complete and definite characterisation of the interesting acidic constituent of the oil. Efforts to obtain more oil had not been entirely abandoned when a paper² dealing with this same exudate appeared, the authors being A. R. Penfold and F. R. Morrison, Technological Museum, Sydney, who, at the request of Mr Lane-Poole and with material supplied by him, examined the question of the economic importance of the exudate.

In view of this publication, and as our results do not confirm the molecular composition for the acidic constituent arrived at by these authors, it has been deemed advisable to publish our own conclusions as to its composition.

For the purpose of facilitating description we propose the name "pentaspadonic acid" for the principal constituent of the exudate, and as such it (with derivatives) will be referred to in this paper.

The exudate as submitted to us was almost black in colour, with a characteristic odour suggesting fish oil. Its acidic character was at once apparent by formation of metallic salts and almost complete soapy solution in aqueous sodium hydroxide. To the alcoholic solution ferric chloride imparted a violet colouration indicative of a phenolic group.

² Royal Society, N. S. Wales, vol. LXII, 218-224.

The following results of preliminary examination were recorded —

$d_{15.5}$ 1.007

n_D^{20} 1.5284

Acid number, 122

Saponification number, 127

Iodine value (Wijs $\frac{1}{2}$ hour), 190

Acetyl value, 130

Ash left on ignition, 15%

Loss on heating in steam oven for two hours, 2-4%

For separation of acidic or phenolic constituents from non-acid material, solution in dilute alcoholic sodium hydroxide solution was resorted to. The alcohol was expelled on the water bath, finally *in vacuo*, and the resulting dry soaps exhaustively extracted with boiling petroleum ether (This method was found to give better results than the use of aqueous sodium hydroxide as a reagent owing to the difficulties of extracting soapy solutions with ether). In this way about 5 per cent of the original exudate was extracted by the solvent and constituted non-acid material. Its small amount precluded examination, but it evidently contained a hydrocarbon which separated from alcoholic solution in crystals melting at 53°C and appeared from combustion results to possess the molecular composition $\text{C}_{24}\text{H}_{40}$.

The residue of dry soaps from the petroleum ether extraction were dissolved in water and the solution acidified, resulting in the separation of a dark-brown oil similar to the original exudate.

For this purified acid material the following constants were observed —

$d_{15.5}$ 1.018

n_D^{20} 1.5280

Acid number, 137

Acetyl value, 130

Iodine value, 190*

Combustion Results —

Found C — 76.8 H — 9.5

$[\text{C}_{21}\text{H}_{34}\text{O}_2 \text{ requires C} - 77.1 \text{ H} - 9.6]$

Silver Salt — The silver salt, prepared by adding silver nitrate to the neutral solution of the acid in alcohol, darkened rapidly on standing. A residue of 22% of silver was left on ignition.

Lead Salt — The lead salt was precipitated from the neutral solution with lead acetate. It was almost insoluble in ether. Evidently a basic salt, it contained 36.2% of lead.

* Owing to its phenolic group the iodine values of the free acid were probably in excess of the true value.

Barium Salt — The barium salt, prepared by adding barium chloride to the neutral solution, contained 16 per cent of barium

Insoluble Bromides — Insoluble bromides separated from acetic acid solution on adding a slight excess of bromine. The yield was 25·7 per cent of the original acid. The percentage of bromine was determined as 46·2

[$C_{22}H_{22}O_5Br_4$ requires 47·2%]

Attempted Esterification of the Acid — As the acid could not be distilled under diminished pressure without decomposition, attempts were made to esterify it in the usual way, but all attempts were unsuccessful, the original acid being recovered unchanged. We regard this inability of the acid to undergo esterification in the usual way as being due to steric hindrance, and of important significance with regard to its structure.

Methylation of the Acid — The methyl ether of the methyl ester could, however, be readily prepared by using dimethyl sulphate and sodium hydroxide as methylating reagents, the phenolic group⁴ undergoing methylation at the same time as the esterification of the carboxyl group. The methyl ether ester as so prepared proved to be very stable and distillable almost to the last drop, under diminished pressure, without decomposition, as a clear colourless liquid. It was accordingly distilled completely at 5 mm. pressure, for purposes of clarification and without any attempts at fractionation in order to record the constants of the complete sample, which were determined as follows —

d_{15}^{20} 9733

n_D^{20} 1·5018

Iodine value, 169

Boiling point range, 240–245° C at 5 mm. pressure

No optical rotation was observed, pointing to the absence of asymmetric carbons.

Combustion Results —

Found C — 78·4 H — 9·8

[$C_{22}H_{22}O_5$ requires C — 77·8 H — 9·6]

Methoxyl Determination — A determination of methoxyl groups by Zeisel's method gave the following result —

1·9562 grammes gave 2·19 grammes Ag I

This corresponds with two methoxyl groups, one of necessity present in the methyl ester group, the other as the methyl ether of the one phenolic group in the acid.

⁴ The presence of one phenolic group was indicated by the acetyl value determined in preliminary analysis. The methoxyl group obtained on methylation remains unchanged in most of the substances described subsequently.

Fractionation of the Methyl Ester—In order to determine the homogeneity or otherwise of the ester, fractional distillation at 5 mm pressure was resorted to. The bulk of the oil boiled within a narrow temperature range 235–240° C. A small higher boiling fraction was, however, eliminated in this way, but the ester appeared undoubtedly to be largely one individual substance.

For the main fraction the following constants were determined —

$d_{15.5}$ 9754

n_D^{20} 1.5108

Iodine value, 130

Combustion Results —

Found C = 78% H = 9.7%

Hydrolysis of the Methyl Ester — It quickly became apparent that the methyl ester—we believe, owing to steric hindrance—was remarkably resistant to hydrolysis, thereby offering a parallel to the non-esterification of the acid by the usual methods and possibly accounting for the natural occurrence of the free acid. It was found necessary to heat the ester with concentrated alcoholic sodium hydroxide solution for at least ten hours to complete hydrolysis. The alkaline liquor so obtained was exhaustively extracted with ether before acidification. This served to eliminate a small amount of neutral material, possibly the methyl ether of a phenolic body (with no carboxyl group) which, we believe, is present in the exudate to a small extent.

On acidification of the alkaline liquor an oily acid separated, which in contrast to the original acid of the exudate could be readily distilled under diminished pressure (5 mm) without decomposition.

The distilled acid—pentaspadonic acid methyl ether—was a pale-yellow liquid at ordinary temperatures, but solidified during a cold night or if placed in the refrigerator. The melting point was determined as 15° C.

The following constants were determined —

$d_{15.5}$ 9972.

n_D^{20} 1.5200

Boiling point, 252–255° C (5 mm)

Acid number, 143

Saponification number, 145

Iodine value, 120.

Combustion Results —

Found C = 77.6 H = 9.6

[$C_{22}H_{38}O_2$ requires C = 77.4 H = 9.7]

Methoxyl Determination —

3728 gramme gave 2244 gramme AgI corresponding to one methoxyl group

Silver Salt—The silver salt darkened rapidly on keeping. The silver content was determined as 22.6%, corresponding to a molecular weight of 372.

Sodium Amalgam, acting in alcoholic solution, was found to have no reducing action on the acid.

Re-methylation of Pentaspadonic Acid Methyl Ether—For the subsequent experiments the methyl ester prepared by remethylation of pentaspadonic acid methyl ether was used. Although it differed little in constants from those previously described for the methyl ester, its preparation from purified pentaspadonic acid methyl ether was deemed advisable, in order to obtain a methyl ester free from any possible impurity not eliminated in the original methylation, such as the methyl ether of a phenol.

Crystalline Tetra Hydro Methyl Pentaspadonate Methyl Ether—In order to reduce the two unsaturated linkages and in the expectation of obtaining crystalline derivatives, pure dry hydrogen was led into a constantly shaken solution of the methyl ester (25 grammes) in ether or methyl alcohol (100 ccs) containing in suspension 2 grammes of platinum dioxide, an adaptation of the method of Vorhees and Adams*. Saturation was rapid and the passage of hydrogen continued until the solution no longer decolourised bromine. The platinum black was removed by filtration, after a preliminary shaking with air, and sufficient of the solution evaporated to allow of crystallisation on cooling. The yield of solid material was almost quantitative. After several recrystallisations from alcohol the substance separated in beautiful plates melting at 44° C.

Combustion Results—Numerous combustion results, carried out to accurately characterise the substance gave as a typical result—

C = 77.0 H = 10.8

[C₂₃H₄₂O₄ requires C = 76.9 H = 10.8]

Methoxyl Determination—

208 grammes gave 230 grammes CH₃I
indicating two methoxyl groups.

Molecular Weight Determination—This was determined by the freezing point method, using benzene as solvent. Mean of several determinations, 385.

Tetra Hydro Pentaspadonic Acid—This was obtained as a by-product from the Zeisel determination of methoxyl in the crystalline ester. After recrystallisation from alcohol it melted at 88° C. The phenolic group, being now free, reacted with ferric chloride to give a violet colour similar to that from the original acid.

Tetra Hydro Pentaspadonic Acid Methyl Ether—This was obtained by hydrolysis of the crystalline ester, a similar hindrance to hydrolysis

* Journal American Chemical Society, 1922, 44, 1397

to that noted above in the case of the unsaturated ester being shown. The acid, after recrystallisation from alcohol, melted at 85°C .

Combustion Results—Repeated analysis gave as a typical result—

Found C = 76.7 H = 10.7

$[\text{C}_{14}\text{H}_{20}\text{O}_2$ requires C = 76.6 H = 10.7]

Acid Number—The acid number was determined as 147

Silver Salt—The silver salt, which did not darken like the silver salts of the unreduced acids, left on ignition a residue of 22.6% of silver.

This agrees with an approximate molecular weight of 375.

Oxidation of the Unsaturated Ester, Methyl Pentaspadonate Methyl Ether—Twenty-five grammes ester dissolved in acetone were treated gradually with finely sieved potassium permanganate (100 grammes).

The acetone solution was allowed to boil during the oxidation, which was completed at the boiling point. Separation of the precipitated manganese dioxide, containing the potassium salts of the acids produced, was followed by its repeated extraction with boiling water. The aqueous extract, which gave good qualitative tests for oxalic acid, was concentrated to a small bulk and acidified with sulphuric acid. A pronounced odour of lower fatty acid was noticed in the resulting liquor, and steam was accordingly passed in to remove volatile acids, the bulk of the acids being, however, not volatile. The volatile acid was identified as hexoic acid by the silver salt method.

(Found Ag = 48.4, silver hexoate requires Ag = 48.4)

The non-volatile acid,^a isolated by ether extraction, showed no tendency to crystallise.

Methoxyl Determination—

2054 gramme gave 3102 gramme AgI corresponding to two methoxyl groups.

Silver Salt—The silver salt left on ignition a residue of 25.9% of silver.

$[\text{C}_{17}\text{H}_{23}\text{O}_5\text{Ag}$ requires 26.0% Ag]

Esterification of the Acid—For purposes of purification and in order to test its homogeneity, the acid oxidation product was converted into methyl ester by refluxing with methyl alcohol and concentrated sulphuric acid for four hours. The resulting methyl ester was fractionally distilled, but almost the whole was collected at a constant boiling point (192°C , 5 mm.) as a colourless liquid. It was fully saturated and the high boiling point indicated a degree of complexity not far removed from the original unsaturated ester from which it was derived. It proved, however, to be the ester of a dibasic acid.

^a The homogeneity of this acid follows from that of its dimethyl ester described later.

Combustion Results—

Found C = 66.9 H = 8.1

[$C_{18}H_{20}O_8$ requires C = 67% H = 8.1%]

Methoxyl Determination—

1102 grammes gave 2372 grammes Ag I

indicating three methoxyl groups, two as ester groups

*Hydrolysis of the Dibasic Ester—*This was effected by prolonged hydrolysis with sodium ethoxide solution during several hours, a similar hindrance to hydrolysis to that previously noted being shown. The resulting acid did not crystallise, but remained as a very viscous oil. The sample obtained in this experiment was apparently still contaminated with a small proportion of unhydrolysed mono methyl acid ester as is indicated by the silver salt determination, the percentage of silver being somewhat low.

*Silver Salt—*The silver salt left on ignition a residue of 36.3% of Ag

[$C_{18}H_{20}O_8Ag_2$ requires 42.5%]

The products obtained on oxidation of the unsaturated methyl ester were, therefore, hexonic acid, oxalic acid, and the mono methyl ester of a dibasic acid in which the methyl ester group of the original unsaturated methyl ester remained unaffected during the oxidation, the free acid group being formed in the oxidation. The retaining of the ester group unimpaired throughout the oxidation has an important bearing on the constitutional problems involved, as it indicates that the carboxyl group of pentaspadonic acid is either directly attached to the nucleus or by means of a saturated side-chain. Our choice of the methyl ester instead of the free acid (methyl pentaspadonic acid) for oxidation purposes was made in order to test this aspect of the constitutional problem, an acetone solution of permanganate being used in view of the specific disruptive action of this reagent at double linkages.

In this connection it may be mentioned that a saturated glyceride such as tripalmitin may be recovered unchanged from boiling acetone permanganate, and the oxidation experiment described here is evidently a close parallel.

The attachment of the carboxyl group of pentaspadonic acid either directly to the nucleus or by means of a saturated side-chain is also indicated by the negative action of sodium amalgam on this acid. In view of the production of oxalic acid on oxidation, any unsaturated linkage present in this side-chain must have occupied the $\alpha\beta$ position with respect to the carboxyl group, and such unsaturated acids are reduced by sodium amalgam.

DISCUSSION OF THE RESULTS

The results of the investigation recorded in the preceding work, although insufficient to admit of definite characterisation of the

* The value obtained, 36.3%, was much too close to that required for a dibasic acid to admit of any doubt as to its nature.

pentaspadonic acid, nevertheless are sufficiently complete to admit of reasonable conclusions being drawn. We have no doubt that a more detailed examination along the lines indicated (which unfortunately could not be further continued owing to exhaustion of supplies) would result in complete elucidation of the constitution of this interesting acid. We have adopted the well-established procedure of placing most reliance on the analytical results obtained from crystalline products from which our formulæ have been calculated as a basis, but it will nevertheless be found that there is fair agreement with predicted results even with liquid products.

The difficulty of deciding between two homologous formula such as $C_{25}H_{42}O_6$ and $C_{30}H_{44}O_8$ is very real when the molecular weights* are high as in the present instance, but we put forward the view, as the result of our investigation, that the exudate of *Pentaspadon motleyi* consists essentially of a monohydric monobasic acid with two unsaturated linkages and of molecular composition $C_{25}H_{34}O_6$. The methyl ether of the methyl ester produced on methylation is of molecular composition $C_{25}H_{40}O_6$, and the monobasic acid (pentaspadonic acid methyl ether) produced on hydrolysis is of molecular composition $C_{24}H_{36}O_6$. Resulting crystalline derivatives obtained by reduction of the methyl ester and subsequent derivatives are respectively—

Tetrahydro pentaspadonic acid, $C_{25}H_{38}O_6$.

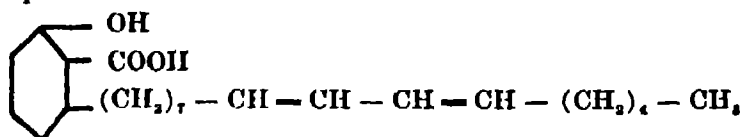
Tetrahydro pentaspadonic acid methyl ether, $C_{24}H_{40}O_6$.

Tetrahydro methyl pentaspadonate methyl ether, $C_{25}H_{44}O_6$.

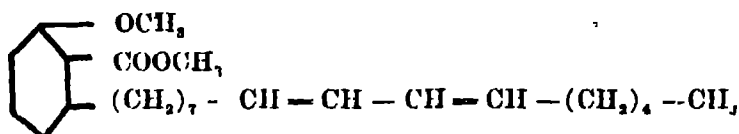
These results agree with the hypothesis of a benzene nucleus (although no simple identifiable benzene derivative has yet been isolated by us). Attached to the benzene nucleus is the phenolic hydroxyl group, and in view of the dibasic acid produced in the oxidation described two additional side-chains, one of which contains the carboxyl group and the other the two unsaturated linkages. The difficulty of esterification of the carboxyl group and the analogous stability of its methyl ester require a steric hindrance factor, and we are, therefore, of the opinion that the carboxyl group must be directly attached to the nucleus. The other side-chain, therefore, contains the whole of the remaining sixteen carbon atoms, with two unsaturated linkages, and this chain is no doubt responsible for the characteristic odour resembling fish oil. The steric hindrance factor, noted in all the products described whether saturated or not, seems further to require that the three groups attached to the nucleus occupy the 1 2 3 positions, but we have no other confirmation of this view, which is therefore tentative. Assuming therefore that the oxalic acid produced in the oxidation is a primary and not a

* Molecular weight determinations do not admit of an accuracy within 10% in such cases.

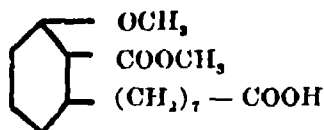
secondary oxidation product, we are led to suggest the following structure for pentaspadonic acid—



The methylated derivative (the unsaturated methyl ester) would then have the structure—



and the acid obtained on oxidation—



We would emphasise that no finality is claimed for this structure of pentaspadonic acid, but it is hoped, if further supplies of material should become available, to continue our work until a final decision can be made.

Reference should be made to the results described by Penfold and Morrison (*loc cit*), in which a molecular composition $\text{C}_{24}\text{H}_{40}\text{O}_4$ is assigned to crude acid isolated from the exudate.

As this formula is based on analysis of crude material, it can make little claim to accuracy and the supposition made by these authors of the presence of two hydroxyl groups is equally erroneous. Our results clearly indicate the presence of but one such group, and this seems also to be borne out by the acetyl values quoted in Penfold and Morrison's paper.

With respect to the negative economic value of the exudate we are in agreement with the views of these authors. Pentaspadonic acid may, however, possess some antiseptic value in view of its phenolic group and similarity of structure to salicylic acid. Of interest in this connection is the use by Malayan natives of the exudate of *Pentaspadon officinalis* mentioned in the introductory section of the paper.

It may finally be observed that the oil possesses little value as a drying oil, the methyl ester remaining practically unchanged for considerable periods on exposure to air.

The authors wish to record their thanks to Messrs White and Francis, of the Government Botanical Staff, for their contributions towards the botanical investigation; to Mr Lane-Poole, for his original supplies of the exudate, and to Mr A R Penfold, Technological Museum, Sydney, who generously placed his residual supply of exudate at our disposal.

Some Experiments on the Treatment of Tick-infested Cattle with Arsenical Dipping Fluids.

By JOHN LEGG, Government Veterinary Surgeon,
and J L FORAN, Chemist, Dept of Agriculture, Townsville

(Communicated by Mr F A Perkins, B Sc Agr, to the Royal Society of Queensland, 24th June, 1929)

INTRODUCTORY

The experiments and observations recorded in this paper deal with the use of solutions of sodium arsenite in the treatment of tick-infested cattle under field conditions, the fluids being applied by immersing the animals in a dipping vat containing the solution under test. The efficacy of any particular line of treatment was determined by collecting all female adult ticks reaching maturity subsequent to treatment, testing these adults for viability by segregating them and determining their ability to oviposit fertile eggs, and comparing these adults both in number and quality with adults obtained from control cattle not subjected to treatment.

A word is perhaps necessary as to the circumstances under which the work was carried out. The dipping vat, an ordinary concrete one containing about 2,200 gallons when full, and having associated with it the usual holding yard, crush, and draining pen, was centrally situated in regard to a small group of well-fenced paddocks. This group of paddocks, protected partly by the high banks of a tidal river on two sides, by a double line of fencing on a third side, and almost wholly enclosed on the fourth side by cultivation paddocks, had been free of ticks for several years prior to the commencement of our experiments. Its situation was ideal for the conduct of the work in hand.

Into this area we introduced, from a remote area outside, many naturally infested cattle carrying large numbers of parasites in all stages of development, and although as the work proceeded we found that some paddocks became infested—particularly those paddocks used for cattle undergoing a course of two dippings, and where there was no attempt to collect ticks reaching maturity between treatments—it was always found possible to close these down and use other clean paddocks, and so carry the work forward.

All treated cattle were allowed grazing under natural conditions after any particular line of treatment, being crush-inspected at least once daily, or more often if thought necessary, and all female adults as they reached maturity were collected. We believe that the methods adopted by us were such as to prevent any female adult from reaching a state of repletion on any of the treated cattle, and leaving the host without being caught at one or other of the examinations which were continued until one could be absolutely certain that the animals were quite free of parasites.

Control cattle were stalled. This was necessary to prevent pasture contamination, as it was utterly impossible to collect 100 per cent of adults reaching maturity on these animals. These adults were set aside in large containers and many millions of larvae produced. When due allowance was made for ticks destroyed or damaged during removal, the number of these adults which proved to be ordinary viable ticks can be set down as approximately 100 per cent. Control cattle were usually clean by the twenty-eighth day after stalling.

Artificially infested cattle were necessary in some experiments, but otherwise the work was performed with naturally infested animals, and it will be noted in many cases that an attempt has been made to classify these animals—certainly a difficult proposition—according to type of infestation, the terms "very heavy," "heavy," "moderate," and "light" being used. Such terms are only relative, but when the controls are examined they convey some idea as to the number of parasites carried by any particular animal.

The whole of the work was conducted in a manner strictly in accordance with the ordinary methods of field practice.

EXPERIMENT I—TO DETERMINE THE EFFECT OF TREATMENT ON THE TICK AT DIFFERENT PERIODS OF ITS PARASITIC LIFE

In order to interpret the results of this experiment correctly, it is necessary to have a clear idea of the main features concerning the parasitic life of the tick.

When cattle are artificially infested, it is found that the larval ticks engorge rapidly during the first four days, and by the fifth day are replete, and have reached a stage just prior to moulting. Odd nymphs appear on the sixth day, but are usually not present in any great number until the seventh day.

The transition period from larvæ to nymphs is short, usually occupying about 48 hours. On many animals nymphs only are present on the ninth day. During the following three days the nymphs engorge rapidly, and young adults may appear on the thirteenth day. Many animals show a considerable number of young adults by the fourteenth day.

The moulting of the nymphs is a process which is spread over several days. Thus, although young adults appear on many animals by the fourteenth day, nymphs can still be found, and sometimes in considerable numbers, up to the seventeenth day. On the eighteenth day, although nymphs are uncommon as a rule, they can occasionally be seen, and odd ones may be found up to the twentieth day.

The period of parasitism of the female adult is at least six days and usually seven to nine days.

The above conclusions have been arrived at after a series of observations carried out during 1926 and 1927 by one of us (J.L.), and they correspond fairly closely to the parasitic life history of the American cattle tick as recorded by Graybill and others.

In November, 1927, fifteen young cattle, ranging from one to three years of age, and all of which had been subject to moderately heavy natural infestation over a considerable period of their lives, were selected, cleansed of ticks, and then allowed grazing under circumstances which precluded any possibility of natural infestation.

Several weeks afterwards, when their skins had cleaned up and the cattle had improved considerably in condition, they were heavily infested with larval ticks raised artificially in the laboratory. Each animal received several thousand larvæ. After infestation the animals were again allowed to graze naturally, and periodic "crush" inspections showed the ticks to be developing in a perfectly normal manner. Hundreds could be counted on most animals.

The dipping fluid used contained 8 lb arsenic (As_2O_3), 4 lb caustic soda, $1\frac{1}{2}$ gallon Stockholm tar, and 2 lb hard soap per 400 gallons.

The cattle were divided into groups, and dipped once at various periods as shown below —

		Condition of Ticks
Group 1 — 6th day	3 animals	In engorged larval state
Group 2 — 10th day	3 animals	In young nymphal state
Group 3 — 14th day	2 animals	Mostly in engorged nymphal state some young adults present
Group 4 — 17th day	2 animals	Mostly in young adult state, a few engorged nymphs
Group 5 — 19th day	2 animals	In adult state, some in latter half of parasitic adult stage
Group 6 — 21st day	2 animals	Mostly in last half of parasitic adult stage, some younger adults also present

One animal was retained as a control

It should be added here that, as many female ticks were rapidly approaching maturity, the animals which were to be dipped on the twenty-first day as well as the control were removed from pasture at the end of the nineteenth day to prevent pasture contamination. Similarly, those cattle dipped on the nineteenth day were also removed from pasture directly after being dipped. All five cattle were placed in stalls and fed artificially during the rest of the experiment.

After treatment all cattle were subject to close and frequently repeated inspection, and as female adults became engorged they were removed just prior to natural detachment, segregated in the laboratory, and their subsequent history followed. Where female ticks were engorging in large numbers, as happened in the case of some of the stalled cattle, it was only natural that a few should be lost in the bedding during the night, but the number obtained was sufficient to warrant our conclusions.

In the case of one animal (No. 282) dipped on the twenty-first day, many females were obviously within a few hours of complete engorgement at the time of treatment, and some of them had actually reached this stage. Probably a few females had dropped from the animal into the bedding during the previous 24 hours.

The results are set out in the following table (Table IA). In reading this table it will be noted that we have kept separate each daily (24-hour) batch of engorged females and have calculated the number which oviposited, number of eggs, &c. Females which fail to oviposit can easily be distinguished, and are removed as they die from the containers. From the mass of eggs produced an average is made as to the number supplied by each female, usually by weighing the egg mass and calculating on the basis of 25,000 eggs to the gram. The mass of eggs is then supplied with moisture, and if hatching takes place a rough estimate as to the percentage of fertile eggs is made from a macroscopic appearance of the mass. This method is one which is adopted throughout this paper, and although it does not give the total number of female survivors which oviposit fertile eggs, because many females which oviposit fail to produce fertile eggs, it does give a rough estimate of the actual number of larvae produced from the surviving ticks from different animals.

TABLE IA

TABLE SHOWING THE EFFECT OF A SINGLE DIPPING ON TICKS IN VARIOUS STAGES OF DEVELOPMENT

8 lb arsenic (As_2O_3), $1\frac{1}{2}$ gallon tar, 2 lb hard soap, caustic soda q s per 400 gallons of solution

November, 1927

No of Animal	Age of Ticks in Days at date of dipping	Day after Imposition (Ticks removed)	Number of Engorged Females	Number of Females Ovipositing	Average Number of Eggs	Approximate % Hatching	Longevity of resultant Larvæ Days	Remarks
292 293 294	6* 6 6	No engorged females			removed			
289 290 291	10 10 10	No engorged females 24th 24th 26th 28th 29th 33rd	1 1 1 1 2 1	1 2 1 1 2 Nil	600 1,000 800 400 250	90 80 Nil Nil 60	40 25 10	Total engorged females, 8 Total engorged females ovipositing, 7
287 288	14 14	No engorged females 25th	2	1	300	Nil		Total engorged females, 2 Total engorged females ovipositing, 1
285 286	17 17	29th No engorged females	1	1	250	Nil		Total engorged, 1 Total ovipositing, 1
283 284	19 19	25th 26th 26th 26th	1 1 3 4 6	1 Nil 2 3 6	500 200 800 1,000	Nil Nil 50 90	48 29	Total engorged females, 15 Total engorged females ovipositing, 12
281 282	21 21	22nd 23rd 24th 25th 26th 22nd 23rd 24th 25th 26th 26th	481 136 26 13 2 208 124 54 22 10 1	431 117 24 11 Nil 176 119 26 22 10 1	760 2,000 1,750 1,600 1,400 1,600 2,000 1,000 800 600	Nil 50 50 75 10 20 75 75 75 75 60	68 72 71 55 55 68 57 71 34	Total engorged females, 1,077 Total engorged females ovipositing, 916
295	Control		Total engorged females			removed, 800, approximately 100 per cent viable		

* The actual immersion or dipping of the animals was carried out at the end of the twenty four hour period representing the sixth day, tenth day, &c

We consider the following observations are worth recording.—

In the case of those cattle dipped on the sixth day, a few ticks (about one dozen altogether) continued to develop, and some actually

reached the young adult stage. They did not appear to be capable of developing further and were all dead before the twenty-seventh day.

On those cattle dipped on the fourteenth day, many nymphs moulted after dipping (about 200 altogether), and reattached. A few partly engorged, but except for those recorded as having reached a stage of repletion the remainder died before reaching complete maturity. The animals were all clean on and after the thirty-fifth day.

On a second occasion during the month of April, when the dipping vat was charged with a well-known proprietary solution at the rate of 8 lb arsenic (as As_2O_3) per 400 gallons, together with certain emulsifying bodies, the experiment was repeated.

Three animals were dipped on the sixth day, three on the tenth day, three on the fourteenth day, two on the seventeenth day, two on the nineteenth day, and two on the twenty-first day after infestation. The results are summarised as follows —

Group I—Three animals dipped sixth day after infestation. No ticks reached maturity.

Group II—Three animals dipped tenth day after infestation. One animal yielded no ticks, a second animal yielded an engorged female on the twenty-third day after infestation, which tick oviposited approximately 900 eggs, of which 40 per cent hatched. The third animal yielded two female ticks on the thirty-second day after infestation, which ticks oviposited an average of 600 eggs each, of which 75 per cent hatched.

Group III—Three animals dipped fourteenth day after infestation. Two animals yielded no ticks while the third yielded five (on the twenty-fourth and twenty-fifth days). Of this number one tick failed to oviposit, while the other four oviposited an average of 800 eggs each, of which 60 per cent hatched.

Group IV—Two animals dipped seventeenth day. One animal yielded three ticks, two failing to oviposit, the other ovipositing approximately 1,200 eggs, which proved non-fertile. The other animal yielded one tick on the twenty-fourth day, which tick oviposited approximately 1,200 eggs, of which 80 per cent were fertile.

Group V—Two animals dipped nineteenth day. One animal yielded 408 engorged females (twenty-first and twenty-fifth days) of which 328 oviposited an average of 2,000 eggs, the remaining ticks failing to oviposit, 50 per cent of the eggs proved fertile. The other animal yielded 136 engorged females, of which 60 oviposited an average of 2,000 eggs, 40 per cent of eggs proving fertile.

Group VI—Two animals dipped twenty-first day. One animal yielded 193 engorged females, 184 of which oviposited an average of 1,600 eggs, 20 per cent of eggs proving fertile. The other animal yielded 385 engorged females, of which 120 oviposited an average of 1,200 eggs, 20 per cent of eggs proving fertile.

The controls yielded 914 and 298 engorged females respectively, 100 per cent of which were normal viable ticks

In order to obtain further evidence on the same point, we treated two naturally infested animals (Nos 316 and 317) carrying ticks in all stages of development as shown in the Table below After treatment these two animals with the controls were examined for maturing females, which were set aside for further observation The results are shown in Table Ia —

TABLE Ia

Dip contained 8 lb arsenic, 1½ gallon Stockholm tar, 2 lb hard soap per 400 gallons

November, 1927

Day after Dipping	Number of Ticks removed	Number Ovipositing	Average Number of Eggs	Average % Hatching	Longevity of Larvae (days)	Remarks
1st	28	14	1,400	No 316 20	77	Animals examined daily up to twenty eighth day after treatment
2nd	22	14	1,000	40	35	
3rd	7	2	100	Nil		
17th	1	1	400	Nil		
19th	2	2	500	80	56	
1st	88	48	1,000	No 317 Nil		No engorged ticks found after fourth day
2nd	14	10	1,300	50	73	
3rd	4	Nil				
4th	5	2	400	80	70	

Controls—

No 318—3,561 } engorged females removed, approximately 100 per cent viable
No 319—3,181 }

DISCUSSION

Examining the first two experiments together, we note the following —

No ticks reached maturity on any of the cattle carrying ticks six days old Odd ticks reached maturity on the cattle dipped on the tenth day Some of these ticks produced viable eggs From the five cattle dipped on the fourteenth day, a small number of mature ticks was again obtained, some of these also ovipositing viable eggs Similarly, the cattle dipped on the seventeenth day produced but few mature females

On the nineteenth day and after, however, the number of survivors is liable to be markedly increased With the dipping fluid containing Stockholm tar and soap as adjuvants, there were not so many survivors as when the cattle carrying ticks of the same age were dipped in the proprietary mixture, but we are not prepared to say that this indicates any great difference in the "tickicide" value of the medicaments concerned It has been noted that, when a number of cattle are artificially infested, with some individual animals the parasitic period of the tick is apparently slightly shorter on the average than with other cattle, thus the first

engorged females appear on some during the twentieth day, whilst others do not give rise to similar female ticks until the twenty-second day or even later. This variation may account for the apparent difference between the cattle dipped in the two medicaments on the nineteenth day, because it appears to be somewhere about this time, i.e., the nineteenth day, when the female adult has completed about three or four days of parasitism, or is about halfway through the parasitic adult period, that its resistance to treatment with arsenical fluids increases.

All the four cattle dipped on the twenty-first day yielded large numbers of engorged females, and although the mortality amongst these was high, there still remained a large number of females which oviposited viable eggs in considerable quantities. The larvae arising from some of these eggs when tested for longevity lived for many weeks, and prevented no difference from larvae raised from normal females.

Seeing that the female adult tick spends at least six days* and usually seven to eight attached to its host, its period of resistance corresponds to approximately the last half of parasitic adult life.

Cohen², in a series of observations on naturally infested cattle sprayed and dipped in various strengths of arsenical dipping fluids, drew the conclusion amongst others that the surviving females mostly represented ticks which were in the pre-adult stage at the time of treatment. He advanced the suggestion that the engorged nymph just prior to moulting was protected by the skin of the old moult, or, in other words, was doubly protected by the two integuments.

This observer apparently did not examine his experimental cattle for a longer period than five days after treatment, during which period no female in the pre-adult stage at the time of treatment could possibly reach maturity. It appears, too, that none of the surviving females were tested in regard to their ability to oviposit fertile eggs.

The weight of evidence, we think, is entirely opposed to such an hypothesis. In the first place those cattle treated on the fourteenth and seventeenth days—particularly those treated on the fourteenth—carried numbers of ticks in a stage just prior to moulting, yet only odd ticks reached maturity on these animals. Examination showed that within forty-eight hours these nymphs, as well as the young recently hatched adults, were mostly dead and commencing to shrivel up while still attached to the host.

Secondly, if this theory regarding the greater resistance of the tick during or just prior to the second moult were correct, then, when naturally infested cattle carrying ticks in *all stages* are treated with standard arsenical dipping fluids—seeing that the average female occupies seven to nine days of parasitism, and there is no reason to believe that this period is shortened by the application of arsenical dipping fluids—there should be a greater number of females reaching

* This period has been determined by one of us (J.L.) after observations made on some thousands of ticks.

maturity during the *second week* after treatment than during the first week, for it will be during the second week that such resistant ticks ultimately reach maturity

If we refer to Table Ia we find that this does not happen, but that the great majority of survivors capable of producing fertile eggs not only reach maturity during the first week, but *during the first half of that week or the three or four days immediately following treatment*. Field evidence therefore supports the view we have expressed

It has been clearly shown that if artificially infested cattle are treated at a time when the whole of the nymphs have moulted (nineteenth and twenty-first day after infestation), and when large numbers of females are within two or three days of reaching maturity, the number of survivors from such animals capable of producing fertile eggs is considerably greater than when similarly infested animals are treated when the parasites are in an earlier stage of development (sixth, tenth, fourteenth, and seventeenth days)

Although we speak of the tick as being in a resistant stage during the last three or four days of parasitic life, the term is only used in a comparative sense. That the vast majority of ticks, even up to nearly 100 per cent, in all stages of parasitism may be occasionally destroyed by a single application of a medicament containing much less arsenic than the standard dip, will be shown later on in this paper

Conclusion—The female adult tick, particularly during the last two to four days of parasitic life, or what corresponds to the last half of parasitic adult life, is much more resistant to treatment with arsenical dipping fluids than at any previous period of parasitism

EXPERIMENT II—TO DETERMINE THE EFFECT OF TREATMENT IN PREVENTING INFESTATION WITH LARVAL TICKS

The eighteen animals used in the first part of this experiment had previously been naturally infested with ticks over a prolonged period. They were cleansed of the parasites and placed in a clean paddock for approximately three weeks, during which time they improved somewhat in condition

The medicament used contained 7 lb arsenic (as As_2O_3) per 400 gallons, $1\frac{1}{2}$ gallon tar, 2 lb hard soap, caustic soda q s. The experiment was carried out in December

After dipping the cattle were divided into nine groups of two each. Eight groups were infested as follows.—One each at the end of the third, sixth, twelfth, eighteenth, twenty-fourth, forty-eighth, and seventy-second hour after dipping. The two animals in the control group yielded 279 and 234 engorged females respectively. No ticks reached engorgement on any of the dipped cattle, except in the case of one animal infested seventy-two hours after dipping. This animal produced three female adult ticks, all of which oviposited, yielding an average of 2,000 eggs, of which 50 per cent. proved fertile.

A second experiment was carried out in January, the medicament on this occasion varying somewhat from the above experiment in that it contained 6 lb arsenic (as As_2O_3) per 400 gallons, double the quantity of emulsion, however, was added to the dipping solution—i.e., 3 gallons tar, 4 lb hard soap, &c. Fifteen animals were used, of which two constituted controls and yielded fourteen and twenty engorged female adults respectively. Of the remaining thirteen which were dipped, two were infested at the twenty-fourth hour, three at the forty-eighth hour, three at the seventy-second hour, two at the ninety-sixth hour, and three at the one hundred and twentieth hour following treatment.

Of the three animals treated at the forty-eighth hour, one yielded two female adults, both of which oviposited approximately 1,000 eggs, 80 per cent of the resultant mass of eggs proving fertile. Of the three cattle infested at the seventy-second hour one yielded no adults, the second yielded five, all of which oviposited, yielding an average of 1,500 eggs, with a 70 per cent fertility of the mass of eggs produced, while the other animal produced one adult which oviposited approximately 1,000 eggs, with a 75 per cent fertility. None of the other animals yielded adult female ticks.

We are not able to give any explanation as to why so few ticks reached maturity on the controls.

The observation was repeated for a third time in May, the dipping solution on this occasion containing 6 lb arsenic (as As_2O_3) per 400 gallons, 1½ gallon tar, &c., eleven animals being used, of which one served as a control and yielded 4,625 engorged female ticks. After dipping, the ten animals were divided into groups and infested at the twenty-fourth hour (three animals), forty-eighth hour (two animals), seventy-second hour (two animals), and ninety-sixth hour (three animals).

No ticks reached maturity on the cattle infested at the twenty-fourth hour.

One animal infested at the forty-eighth hour yielded one female, ovipositing approximately 800 eggs, of which 90 per cent proved fertile.

Of the two animals infested at the seventy-second hour, one yielded five ticks which oviposited an average of 800 eggs each, 90 per cent of the resultant egg mass proving fertile, while the other yielded one tick which oviposited approximately 200 eggs, of which 75 per cent hatched.

Of the three animals treated at the ninety-sixth hour, all yielded fertile ticks. One yielded 100 adults, ninety-seven of which oviposited an average of 1,500 eggs, with a fertility of 90 per cent, the second yielded eleven adults, six ovipositing an average of 600 eggs, with a 90 per cent fertility, while the third yielded four adults, one of which oviposited 1,500 eggs, with a 75 per cent fertility.

DISCUSSION

The experiment shows that cattle can be infested with larval ticks forty-eight hours after treatment in dipping solutions containing considerable quantities of arsenic, together with an emulsion of tar and soap.

Although no larval ticks developed on those cattle infested up to the forty-eighth hour in the first experiment, in the second experiment, when the amount of emulsion was doubled, one animal infested at the forty-eighth hour eventually produced two mature viable female ticks.

In the third experiment the cattle infested at the twenty-fourth hour again remained clean of parasites, whilst some of those infested at the forty-eighth hour or later produced mature adults capable of ovipositing fertile eggs.

Conclusion—Up to the twenty-fourth hour after treatment in solutions of arsenic of a strength approximating that of the standard dip (8 lb As_2O_3 per 400 gallons), and containing considerable quantities of emulsion of tar and soap, cattle remain immune to infestation with larval ticks. At the forty-eighth hour or later infestation is liable to occur.

EXPERIMENT III—TO DETERMINE WHETHER ANY BENEFICIAL EFFECT IS PRODUCED ON THE TICK BY PERMITTING CATTLE TO ENTER WATER SOON AFTER TREATMENT

After considerable field experience in the treatment of tick-infested cattle with arsenical dipping fluids, we have been led to form the conclusion that, if recently treated cattle are allowed to enter water, the effect of the treatment (as might naturally be expected) is seriously interfered with. We have noticed that during the months of January, February, and March in North Queensland many cattle have a habit of standing for long hours during the day almost wholly immersed in water. They do this as a rule to avoid the attacks of biting flies.

Travelling cattle which are dipped at various points on the main stock routes in Queensland, when such cattle are being moved from tick-infested to clean country, are usually yarded overnight and dipped the following morning. As the dips are frequently built on the banks of lagoons or where there is a considerable quantity of surface water, it not infrequently happens that treated cattle, soon after being released from the draining pens, proceed to the drinking water and enter it if permitted. An experiment was therefore designed to test the effect of permitting cattle to enter water after having recently been treated.

Seventeen head of cattle were used, fifteen being treated twice with a five-day interval in a fluid containing 7 lb arsenic (As_2O_3), 3 gallons Stockholm tar, 4 lb hard soap, caustic soda q.s. per 400 gallons. Ten animals were allowed to enter water within a few minutes after each treatment and remained therein for one hour, the other five animals were precluded from doing so. Two untreated beasts acted as controls. After treatment all the cattle were placed under circumstances which prevented natural infestation, were allowed grazing, and examinations continued for a month after removal from tick-infested pasture.

No record was kept of ticks reaching maturity between the two dippings. The observation was carried out in March, 1928. The results

are set out in the following table (Table III) —

TABLE III

TO SHOW THE EFFECT OF PERMITTING RECENTLY TREATED CATTLE TO ENTER WATER.

Dipping fluid 7 lb. arsenic, 3 gals tar, 4 lb hard soap, caustic soda q s per
400 gallons

March, 1928

No. of Animal	Type of Infestation	Interval between Treatments	Total Mature Females Collected	Total Females Ovipositing	Average Number of Eggs	Average Number of Eggs Hatching	Longevity of resultant Larvae in days	Remarks
442	Moderate	5 days	231	207	1,500	75	24	Entered water and remained therein for one hour after each treatment
443	Heavy		91	76	2,000	60	22	
444	Moderate		44	33	1,500	75	'	
445	Moderate		110	92	1,800	75	41	
446	Heavy		52	45	1,200	90	77	
447	Moderate		68	56	2,000	75	47	
448	Moderate		120	119	1,500	50	58	
449	Light		174	160	1,500	75	73	
450	Moderate	Controls	98	87	2,000	90	63	Did not enter water after treatment
451	Heavy		241	222	1,200	75	67	
*425	Moderate		4	2	1,000	20	47	
426	Heavy		Nil	.				
427	Moderate		Nil					
428	Heavy		Nil					
429	Heavy		1	Nil				
440	Moderate		8,177	Approximately 100 per cent viable				
441	Moderate	6,468						

* These animals (Nos 425 429, 440, 441) also appear in Table VIIX. All the animals shown in Table VIIIX as well as the above belonged to the same lot of cattle i.e., they had all been exposed to natural infestation over a similar period of time, in the same paddock, and removed on the same day. One group of controls only was therefore necessary. Collection of ticks commenced immediately after the second treatment.

DISCUSSION

There is no difficulty in drawing conclusions from the above experiment. The dipping fluid killed an enormous number of ticks on all animals, and actually only quite a small percentage of the parasites escaped destruction (compare with controls) but the difference between the two groups is quite distinct and marked.

It might be considered that, by allowing the animals to remain in the water for an hour partly or almost totally immersed, one is producing a condition of affairs not seen under natural conditions, but this is not so. We have observed cattle enter water in the fly season and remain therein during the whole of the hours of daylight, only coming out to graze after sunset.

The water into which the cattle in the above experiment were driven was not of sufficient depth to totally immerse the animals, as it was only 3 ft 6 in to 4 ft deep. With most of the animals the water came up to approximately the level of the shoulder joint. It was noticeable that practically the whole of the survivors were removed from those portions of the body which were immersed, while on the upper or exposed portions the ticks were almost wholly destroyed.

Conclusion—Permitting cattle to enter water immediately after dipping and remaining therein for considerable periods seriously interferes with the efficacy of the treatment

EXPERIMENT IV—TO DETERMINE THE EFFECT OF RAIN-FALL ON RECENTLY TREATED CATTLE

The dipping fluid used in this experiment contained 8 lb arsenic (as As_2O_3), $1\frac{1}{2}$ gallon Stockholm tar 2 lb hard soap, caustic soda q s per 400 gallons of solution

Eighteen head of cattle which had been exposed to heavily infested pasture for a month were removed on the 24th November, 1927, and seventeen dipped in the ordinary manner

After treatment, sixteen were divided into groups of two each, and gently sprayed for ten minutes from a half-inch hose, the spray being made to simulate as nearly as possible a light shower of rain both in volume and the angle at which it was directed on to the body of the animal. The interval allowed between dipping and spraying with water is shown in the following table

After spraying, the cattle were allowed to graze under natural conditions, and were periodically crush-inspected, so that female ticks were collected and placed aside for further observation

The results are set out in the following table (Table IV A) —

TABLE IV A
November

No of Animal	Type of Infestation	Interval between Dipping and Spraying	Number of Fertile Ticks Removed			
			1st Week	2nd Week	3rd Week	4th Week
320	Heavy	$\frac{1}{2}$ hour	17	24	8	Nil
321	Light					
322	Moderate					
323	Light	1 hour	78	50	10	Nil
324	Heavy					
325	Moderate	2 hours	72	92	1	Nil
326	Moderate					
327	Heavy	3 hours	72	36	10	Nil
328	Light	6 hours	77	7	2	Nil
329	Moderate					
330	Moderate					
331	Very heavy	12 hours	84	24	12	1
332	Light					
333	Light					
334	Light	24 hours	2	3	4	Nil
335	Heavy					
336	Very heavy					
337	Light	Dipped only	27	Nil	Nil	Nil
		Not dipped or sprayed	667	190	96	35

The evidence from the above table shows in the first place that the mortality among all ticks on all treated cattle was high, this being obvious from the number of ticks obtained from the untreated control. The animals sprayed on the eighteenth and twenty-fourth hours after treatment actually showed a higher mortality amongst the parasites than

the dipped control. It was obvious that with these two groups at least the spraying produced no beneficial effect, and the arsenical solution had already worked its effect before the spray was applied.

With all the other groups, however—that is, those sprayed up to the twelfth hour—a considerable number of ticks appeared to be benefited. During the first week nearly all the survivors came off within the first two or three days following treatment, after which there was a short period covering the second half of the week when few ticks were removed. During this period, however, a number of ticks—mostly half-grown adults—which had been previously showing little signs of life, began to increase in size and show evidence of recovery. Many of these reached a state of repletion during the second week following treatment. The larger number of ticks reaching maturity during the second and third week following treatment was evidently due to the beneficial effect of the spray.

We repeated the experiment with certain modifications in May, using thirty animals, including two controls. The results are set out in the following table (Table IVB) —

TABLE IVB

Arsenic (As_2O_3) 6.6 lb, Stockholm tar $1\frac{1}{4}$ gal, hard soap 2 lb, caustic soda q.s. per 400 gallons

May

No of Animal	Type of Infestation	Interval between Dipping and Spraying	Number of Fertile Ticks Removed			
			1st Week	2nd Week	3rd Week	4th Week
511	Heavy	Dipped but not sprayed	453	8	Nil	Nil
512	Moderate					
513	Heavy					
514	Heavy					
515	Light	Sprayed immediately after dipping	67	218	66	16
516	Light					
517	Heavy					
518	Light					
527	Light	1 hour	141	49	24	9
528	Heavy					
529	Light					
530	Moderate					
531	Heavy	2 hours	180	33	30	6
532	Light					
533	Heavy					
534	Light					
535	Heavy	3 hours	60	23	32	5
536	Light					
537	Heavy					
538	Moderate					
523	Light	4 hours	451	46	30	14
524	Heavy					
525	Moderate					
526	Moderate					
519	Light	5 hours	Nil	11	2	9
520	Light					
521	Moderate					
522	Light					
529	Light	Controls	3,697	3,333	2,696	593
540	Moderate					

DISCUSSION

The results from the second experiment largely confirm those obtained from the first. They show firstly a high mortality among all ticks which had passed through the dipping solutions. With the four cattle which were dipped only (and not sprayed) nearly all the survivors were removed during the first four days after treatment, thus confirming the result of Experiment No. 1, which indicated the resistance of the female adult tick during the last four or five days of parasitic life. With all other groups, too, it was noted that nearly all the survivors collected during the first week came off during the first two or three days after treatment.

With all groups sprayed with water there was a tendency for a number of ticks to reach maturity during the second, third, and fourth weeks after treatment, which ticks would have apparently been destroyed had not the spraying been carried out. In some cases the number was actually higher than the number obtained during the first week.

When the two experiments are taken together, we think the following conclusions can be drawn —

Conclusions —

- 1 Even when cattle are treated when a shower is actually falling, the tick mortality still remains high.
- 2 Up to the twelfth hour after treatment light showers may benefit the tick, but only to a slight extent.
- 3 Light showery weather would not seriously interfere with the efficacy of the treatment.

EXPERIMENT V—TO DETERMINE THE EFFECT OF INCREASING THE LENGTH OF THE DIPPING VAT (OR CAUSING THE ANIMALS TO REMAIN IMMERSSED IN THE DIPPING FLUID FOR A LONGER PERIOD)

It was considered, that if any variation occurred as a result of alteration in the length of the dipping vat, this variation would be just as appreciable with a dipping fluid containing smaller quantities of arsenic than that prescribed for the standard dipping fluid as when the standard solution itself was employed. Hence the strength of the fluid for this experiment was fixed at 5 lb As_2O_3 per 400 gallons, and to this fluid was added $1\frac{1}{2}$ gallon Stockholm tar and 2 lb hard soap as emulsion per 400 gallons.

Twenty-two head of cattle, including two controls, were employed. Ten animals were allowed to swim straight through the vat, while ten others were retained in the vat at its deepest part by means of a rope attached to the tail of the beast. While being retained in the dip the animal was forced completely below the surface two or three times by means of pressure applied to the middle of the dorsal region. Each

animal was retained for from ten to fifteen seconds—i.e., a sufficiently long enough period to swim through a vat at least three times the length of the one employed by us

After treatment, grazing was allowed and observations carried out for twenty eight days, under circumstances which precluded natural infestation

The experiment was performed in April, 1928

The results are set out in the following table (Table V) —

TABLE V

Dipping fluid Arsenic (As_2O_3) 5 lb, Stockholm tar $1\frac{1}{2}$ gallon soap 2 lb,
caustic soda 1 lb per 400 gallons
April 1928

Engorged Females Removed 1st Week															
No of Animal	Type of Infestation	Treatment	Days							Total	Number Ovipositing	Average Number of Eggs	Average % Hatching	Remarks	
			1	2	3	4	5	6	7						
489	Heavy	Allowed to pass through dip in ordinary manner		10	17					27	3	200	90	One tick removed from 490 on tenth day no oviposition	
490	Moderate		16	6						20	4	150	50		
491	Moderate		4				9			13	Nil				
492	Light		32	7	4					43	14	900	40		
493	Moderate		14	4						18	5	800	Nil		
494	Moderate		4							4	1	400	Nil		
495	Light		19	1						20	8	500	Nil		
496	Light		4	13						17	11	900	90		
497	Light	Retained in dipping vat for at least 10 seconds longer than ordinarily	4		2					6	2	100	Nil	One tick removed from 504 on twelfth day laid 300 eggs which failed to hatch	
498	Moderate														
499	Moderate		18	2	1					21	2	600	Nil		
500	Moderate		2							2	Nil				
501	Moderate		54	14	2					70	14	700	Nil		
502	Moderate		4	8	1					13	5	500	Few		
503	Light		4	4			2			6	2	150	50		
504	Moderate		4	4						8	4	300	Nil		
505	Light		10	4	1					15	5	300	Nil		
506	Light		32							32	1	400	Nil		
507	Moderate		10		1					11	1	600	Few		
508	Moderate		19	2	2					23	5	600	Nil		
			First Week		Second Week		Third Week		Fourth Week		Total				
509	Light	Controls	2363		1399		216		89		4067				
510	Light		3350		2292		1320		72		7043				

NOTES.—1 No other ticks were removed from any animal except those shown in the table. The last tick which might have oviposited viable eggs was removed, as the table shows on the fifth day after treatment. The whole of the nymphs and larvae on the treated cattle were therefore completely destroyed.

2 The two light controls were evidently classified on the low side and should have been classed as "moderate" or "heavy" infested animals. The experiment was carried out in the early winter when the hair was long, and it was not easy to classify the cattle as many of the smaller ticks were not obvious. Possibly the classification of the treated cattle was also on the low side as it was the invariable custom, where any doubt existed, to class the animal in the lower rather than in the higher category.

3 The longevity of the larvae from surviving ticks was not determined.

DISCUSSION

The experiment calls for little comment. The results show in the first place that a single dipping in a solution containing 5 lb arsenic per 400 gallons may be a highly toxic fluid so far as the tick is concerned, and in this respect compares very favourably with dipping fluids containing considerably larger quantities of arsenic. For the first three days some of the cattle yielded a number of females which oviposited and produced viable eggs, but afterwards only very few ticks were discovered on any of the treated animals, while the controls continued to yield large numbers of normal female ticks.

It is worth noting that considerable numbers of ticks—small female adults mostly—were not entirely destroyed at the time of treatment, but remained alive in a semi-moribund condition for several days afterwards. Such female ticks had probably completed about half of their parasitic life as adults, and had thus already commenced to develop some resistance at the time of treatment. Although the treatment failed to destroy them at once, they eventually died while still attached to the host, in some cases as long as a fortnight later.

The whole of the nymphs and larvae on these animals were completely destroyed.

The cattle which were retained in the dip presented little difference when compared with those cattle which were allowed to swim right through.

Conclusion—Increasing the length of the dipping vat within reasonable limits (or retaining the animal longer in the dipping fluid) does not produce any difference in the ultimate effect of the dipping fluid on the tick.

EXPERIMENT VI—TO DETERMINE WHETHER ALTERATIONS IN THE PHYSICAL CHARACTER OF A DIPPING FLUID, SUCH AS MAY BE BROUGHT ABOUT BY PROLONGED USE, AFFECTS IN ANY WAY THE EFFICACY OF SUCH FLUID

As a result of considerable field experience in the use of both clean and dirty dips, one of us (J.L.) has been led to regard the dirty dip with some suspicion. It has been noticed that the dip which has been in use for some considerable time, and which contains a large quantity of excrement, hair, dirt, &c, washed from the bodies of the cattle, has apparently allowed a considerably greater number of ticks to escape complete destruction than in the case of the clean, freshly charged dip. Theoretically, the arsenic content remaining the same, there should be little difference between the dirty and clean dipping fluids.

The dipping vat used by us had been cleaned out each year for several years and there was an accumulation of dirt, excrement, &c, piled at the side of the dip. It was decided to use this material by thoroughly mixing it with the dipping fluid.

The fluid used consisted of 6 2 lb arsenic as As_2O_3 , and 2.28 lb as As_2O_5 , 4 lb caustic soda, $1\frac{1}{2}$ gallon tar, and 2 lb hard soap per 400 gallons

Twenty-two head of cattle were used in this experiment Two were set aside as controls, ten were passed through before the dirt, &c, was added, and ten afterwards Before the second lot of animals was passed through, care was taken to see that the dirt, &c, was thoroughly distributed throughout the dipping fluid

After treatment the cattle were allowed grazing under circumstances which precluded natural infestation, and all ticks as they reached maturity were collected and set aside for subsequent observation

The observation was carried out in June, 1928 The results are set out in the following table (Table VI) —

TABLE VI
Arsenic (As_2O_3) 6 2 lb, arsenic (As_2O_5) 2 28 lb, Stockholm tar $1\frac{1}{2}$ gal, hard soap 2 lb per 400 gallons
June, 1928

No of Animal	Type of Infestation	Treatment	Number of Fertile Ticks removed			
			1st Week	2nd Week	3rd Week	4th Week
554	Light	Dipping fluid clear	38	3	4	Nil
555	Light		7	Nil	Nil	Nil
556	Moderate		Nil	Nil	Nil	Nil
557	Light		7	Nil	2	Nil
558	Heavy		8	1	1	Nil
559	Light		Nil	2	Nil	Nil
560	Light		4	1	Nil	Nil
561	Moderate		Nil	Nil	Nil	1
562	Heavy		12	Nil	Nil	Nil
563	Heavy		20	4	Nil	Nil
564	Heavy		Nil	Nil	Nil	1
565	Light	Controls	858	4,111	2,236	118
566	Light		1,256	2,022	2,168	236
567	Heavy	Dipping fluid heavily charged with dirt, hair, &c	Nil	Nil	Nil	Nil
568	Light		Nil	Nil	Nil	Nil
569	Heavy		Nil	Nil	Nil	Nil
570	Moderate		Nil	1	Nil	1
571	Light		Nil	Nil	1	Nil
572	Moderate		10	Nil	Nil	Nil
573	Light		6	Nil	Nil	Nil
574	Light		Nil	Nil	Nil	1
575	Light		Nil	Nil	Nil	4
576	Moderate		Nil	Nil	Nil	Nil
577	Light		Nil	Nil	Nil	Nil

Difficulty was experienced in suppressing the growth of moulds in the containers, and it is possible that these interfered with the fertility of some ticks

DISCUSSION

Nearly all the survivors were obtained during the first two to four days after treatment, after which odd ticks were collected from most animals It is impossible to draw any distinction between the two groups, and it is obvious that, where due allowance is made for the

different degrees of infestation of the animals concerned, the efficacy of the dipping fluid was not interfered with by the addition of dirt, excrement, &c

Conclusion—So long as the arsenical content is not disturbed, the efficacy of a dipping fluid is not interfered with by the addition of dirt, &c

EXPERIMENT VII—TO DETERMINE WHETHER TWO TREATMENTS AT SHORT INTERVALS WITH ARSENICAL DIPPING FLUIDS WITH AND WITHOUT CERTAIN ADJUVANTS WILL DESTROY ALL TICKS ON INFESTED CATTLE

Four dipping fluids were used —

- 1 Arsenic (As_2O_3) and caustic soda,
- 2 Arsenic and caustic soda + $1\frac{1}{2}$ gallon tar and 2 lb hard soap per 400 gallons of solution,
- 3 Arsenic and caustic soda + 3 gallons tar and 4 lb hard soap per 400 gallons of solution,
- 4 A proprietary liquid concentrate widely used in Queensland

All of these medicaments were tested at strengths of 6, 7, 8, and 9 lb arsenic (As_2O_3) per 400 gallons of solution, and each strength was tested with intervals of three, five, seven, and ten days between applications

The experiment therefore helps to throw light on the value of an emulsion made up of tar and soap, firstly, as to whether the "tickicide" value of the medicament is increased by the use of such emulsion, and, secondly, whether the emulsion produces any beneficial effect on the skin of the animal. Evidence is also produced on the question of whether any variation in the interval between treatments, other things being equal, affects the ultimate result

The animals were removed from tick-infested country in small groups at a time, treated in the usual manner—that is, crush inspected, classified, numbered for identification purposes—and then immersed in the medicament concerned. They were allowed to stand about twenty minutes in the draining pens, then passed into the open field. One or two controls were set aside from each group of animals concerned

No attempts were made to collect ticks between treatments, but observations showed that on many animals considerable numbers of ticks were reaching maturity during the first two or three days after the initial treatment. After the second treatment, however, inspection commenced at once, and was continued, except where otherwise stated, until the twenty-eighth day after removal from infested pasture. All ticks reaching maturity were removed and segregated for further observation.

The results are set out in the following series of tables —

TABLE VIIA

Arsenic 9 lb, caustic soda q s, adjuvant nil per 400 gallons
September 1927

No of Animal	Type of Infestation	Interval between Treatments	Total Mature Females Collected	Total Females Ovipositing	Average Number of Eggs	Average % of Eggs Hatching	Longevity of Resultant Larvæ
235	Moderate	3 days	11	4	500	70	68 days
236	Light		4	Nil			
237	Very heavy		16	6	300	Nil	
238	Heavy		22	6	300	Nil	
239	Light	5 days	14	7	300	1	31 days
240	Very heavy		Nil				
241	Light		4	Nil			
242	Very heavy		Nil				
243	Moderate	7 days	1	Nil			
244	Moderate		Nil				
245	Very heavy		Nil				
246	Very heavy		Nil				
247	Moderate	10 days	Nil				
248	Very heavy		Nil				
249	Light		1	Nil			
250	Moderate		Nil				
251	Heavy	Controls	Nil				
252	Light		Nil				
253	Heavy		2	1	400	5	17 days
254	Moderate		Nil				
255	Moderate	Controls	4,165	Approximately 100 per cent normal viable females			
256	Moderate		3,757				

TABLE VIIB

Arsenic 9 lb, caustic soda q s, adjuvant 1½ gal Stockholm tar, 2 lb hard soap per 400 gallons
October 1927

No of Animal	Type of Infestation	Interval between Treatments	Total Mature Females Collected	Total Females Ovipositing	Average Number of Eggs	Average % of Eggs Hatching	Longevity of Resultant Larvæ
259	Heavy	3 days	20	Nil			
260	Heavy		16	Nil			
261	Heavy		8	Nil			
262	Very heavy		Nil				
263	Very heavy	5 days	1	Nil			
264	Light		Nil				
265	Heavy		Nil				
266	Moderate		Nil				
267	Heavy	7 days	Nil				
268	Moderate		Nil				
269	Light		Nil				
270	Heavy		Nil				
271	Heavy	10 days	Nil				
272	Moderate		Nil				
273	Light		Nil				
274	Very heavy		Nil				
275	Light	Controls	Nil				
276	Heavy		Nil				
277	Light		Nil				
278	Light		Nil				
279	Light	Controls	1,172	Approximately 100 per cent normal viable females			
280	Light		1,564				

TABLE VIIc

Arsenic 9 lb, caustic soda q s, adjuvant 3 galls Stockholm tar, 4 lb hard soap per 400 gallons

May 1928

No of Animal	Type of Infestation	Interval between Treatments	Total Mature Females Collected	Total Females Ovipositing	Average Number of Eggs	Average % of Eggs Hatching	Longevity of resultant Larvæ
467	Very heavy	3 days	57	Nil	200	Nil	Larvæ still alive 50 days after hatching
468	Light		8	Nil			
469	Heavy		19	Nil			
470	Heavy		8	Nil			
471	Heavy		9	1			
472	Light	5 days	Nil	3	1,200	80	
473	Very heavy		4				
474	Heavy		6				
475	Heavy		Nil				
476	Heavy		Nil				
477	Heavy	7 days	Nil	1	2,000	40	
478	Heavy		Nil				
479	Heavy		1				
480	Heavy		Nil				
481	Heavy		Nil				
482*	Heavy	10 days	61	40	1,100	40	
483	Moderate		1				
484	Heavy		Nil				
485	Light		Nil				
486	Heavy		Nil				
487	Heavy	Controls	11,601	Approximately 100percent normal viable females			
488	Heavy		7,744				

* No 482 A very long haired animal On the first day after the second treatment this animal yielded thirty engorged female adults, twenty five of these oviposited an average of 1,000 eggs each, 30 per cent of the resultant mass of eggs proving fertile, on the second day eight engorged females were removed, one of which oviposited approximately 2,000 eggs, but the fertility was very low, only odd eggs hatching, on the third day seven engorged females were removed of which five oviposited an average of 1,500 eggs each, with 50 per cent fertility, on the fourth day eight engorged females were recovered, seven of which oviposited 1,500 eggs each, with a 50 per cent fertility, eight ticks altogether were removed on the fifth, sixth, and tenth days, of which two only oviposited, but all the eggs proved non fertile No engorged females developed on the animal after the tenth day following the second treatment Some of the larvæ arising from these surviving females were alive and quite active fifty days after hatching

TABLE VIIb

Arsenic 9 lb, adjuvant, emulsion contained in proprietary liquid concentrate
per 400 gallons
August 1927

No. of Animal	Type of Infestation	Interval between Treatments	Total Mature Females Collected	Total Females Ovipositing	Average Number of Eggs	Average % of Eggs Hatching	Longevity of Resultant Larvae
164	Heavy	3 days	5	Nil	40	Nil	
165	Heavy		14	Nil			
166	Heavy		14	Nil			
167	Heavy		11	1			
168	Light		1	1			
169	Heavy	5 days	4	Nil	20	Nil	
170	Heavy		Nil				
171	Heavy		Nil				
172	Moderate		Nil				
173	Moderate		1	Nil			
174	Very heavy	7 days	2	Nil			
175	Heavy		Nil				
176	Very heavy		Nil				
177	Light		1	Nil			
178	Light		Nil				
179	Light	10 days	Nil				
180	Light		Nil				
181	Heavy		Nil				
182	Heavy		Nil				
183	Moderate		Nil				
184	Very heavy	Controls	5,849	engorged females removed first week after stalling			
185	Heavy		3,849	engorged females removed 14 days after stalling			

Approximately 100 per cent of engorged females from controls normal viable females

No counts made of ticks maturing on 184 after seventh day, nor on 185 after fifteenth day, although both animals still carried some thousands of immature ticks

TABLE VIIc

Arsenic 8 lb, caustic soda q s, adjuvant nil, per 400 gallons
August 1927

No of Animal	Type of Infestation	Interval between Treatments	Total Mature Females Collected	Total Females Ovipositing	Average Number of Eggs.	Average % of Eggs Hatching	Longevity of Resultant Larvae
218	Heavy	3 days	5	Nil	1	200	
219	Very heavy		1	Nil			
220	Heavy		2	Nil			
221	Very heavy	5 days	Nil	1	200	Nil	
222	Heavy		Nil				
223	Heavy		Nil				
224	Heavy		6				
225	Very heavy	7 days	Nil				
226	Very heavy		Nil				
227	Heavy		Nil				
228	Moderate		Nil				
229	Moderate	10 days	Nil				
230	Light		Nil				
231	Heavy		Nil				
232	Heavy		Nil				
233	Heavy	Control	Nil				
234	Heavy		5,505				

TABLE VIII

Arsenic 8 lb, caustic soda q s, adjuvant $1\frac{1}{4}$ gal Stockholm tar, 2 lb hard soap per 400 gallons

November 1927

No. of Animal	Type of Infestation	Interval between Treatments	Total Mature Females Collected	Total Females Ovipositing	Average Number of Eggs	Average % of Eggs Hatching	Longevity of Resultant Larvæ
296	Very heavy	3 days	41	7	150	Nil	
297	Very heavy		20	7	150	Nil	
298	Very heavy		19	2	100	Nil	
299	Moderate		3	0	Nil		
300	Very heavy		12	3	150	Nil	
301	Very heavy	5 days	Nil	Nil			
302	Moderate		Nil	Nil			
303	Very heavy		14	2	150	Nil	
304	Very heavy		2	Nil			
305	Very heavy		1	Nil			
306	Very heavy	7 days	1	Nil			
307	Very heavy		2	Nil			
308	Very heavy		2	2	50	Nil	
309	Very heavy		Nil				
310	Very heavy		Nil				
311	Very heavy	10 days	2	Nil			
312	Heavy		2	2	75	Nil	
313	Heavy		Nil				
314	Heavy		Nil				
315	Heavy		Nil				
318	Moderate	Controls	3,561	Approximately 100 per cent normal viable females.			
319	Moderate		3,181				

TABLE VIIIc

Arsenic 8 lb, caustic soda q s, adjuvant 3 galls Stockholm tar, 4 lb hard soap per 400 gallons

April 1928

No. of Animal	Type of Infestation	Interval between Treatments	Number of Engorged Females	Number of Females Ovipositing	Average Number of Eggs	Average % of Eggs Hatching	Longevity of Resultant Larvæ			
452	Moderate	3 days	Nil	.						
453	Moderate		Nil							
454	Heavy		Nil							
455	Light		Nil							
456	Heavy	5 days	Nil							
457	Moderate		Nil							
458	Heavy		Nil							
459	Heavy	7 days	Nil							
460	Moderate		Nil							
461	Light		Nil							
462	Light	10 days	Nil							
463	Moderate		Nil							
464	Moderate		Nil							
465	Moderate	Controls	6,579					Approximately 100 per cent normal viable females		
466	Moderate		3,589							

Examinations completed on twenty third day after removal from tick infested country. From the fourteenth to the twenty-third day ten consecutive daily examinations had failed to locate one tick on any one animal

TABLE VIH

Arsenic 8 lb., caustic soda q s., adjuvant emulsion contained in proprietary liquid concentrate per 400 gallons

May 1927

No of Animal	Type of Infestation	Interval between Treatments	Number of Engorged Females	Number of Female Ovipositing	Average Number of Eggs	Average % of Eggs Hatching	Longevity of Resultant Larvae	
58	Moderate	3 days	17	1	2,000	90	42 days	
59	Light		9	Nil				
60	Heavy		9	1	500	Nil		
61	Moderate		4	Nil				
144A	Heavy	5 days	19	Nil			9 days	
145A	Heavy		16	1	100	Nil		
132	Very heavy		4	1	200	Nil		
133	Very heavy		6	3	1,000	1		
134	Very heavy		10	Nil				
135	Very heavy		2	Nil				
136	Very heavy	7 days	6	1	200	Nil		
72	Moderate		Nil					
73	Light		Nil					
74	Moderate		Nil					
75	Light	10 days	Nil				10 days	
76	Light		Nil					
137	Very heavy		27	12	1,500	30		
138	Very heavy		2	2	1,200	Nil		
139	Very heavy	Controls	Nil				Approximately 100 per cent viable ticks (six days only) approximately 100 per cent viable ticks	
140	Very heavy		1	Nil				
141	Very heavy		30	18	800	Nil		
*92	Light		2,545					
93	Moderate	58 61	3,019					
94	Moderate	72 76	2 906					
142	Very heavy	Controls	5,306					
143	Very heavy	144A, 132 141	4 621					

No counts made on 142 and 143 after sixth day, although these animals still carried some thousands of immature ticks

* See Table VIII and Table VIIIc

TABLE VII

Arsenic 7 lb., caustic soda q s., adjuvant nil per 400 gallons

August 1927

No. Animal	Type of Infestation	Interval between Treatments	Number of Engorged Females	Number of Females Ovipositing	Average Number of Eggs	Average % of Eggs Hatching	Longevity of Resultant Larvæ
202	Heavy	3 days	6	Nil			
203	Heavy		Nil				
204	Light		Nil				
205	Moderate	5 days	17	2	1,500	Nil	
206	Moderate		Nil				
207	Light		Nil				
208	Heavy	7 days	8	1	300	Nil	
209	Light		Nil				
210	Heavy		Nil				
211	Very heavy	10 days	Nil				
212	Heavy		Nil				
213	Very heavy		Nil				
214	Light	Control	Nil				
215	Heavy		Nil				
216	Heavy		Nil				
217	Heavy		Nil				
*234	Heavy		5,505	engorged females removed during first ten days of stalling, after which no further counts were made, although the animal still carried many thousands of immature ticks			

* See also Tables VIIa and VIIc.

TABLE VII

Arsenic 7 lb., caustic soda q s., adjuvant 1½ gal Stockholm tar, 2 lb hard soap per 400 gallons

December 1927

No. of Animal	Type of Infestation	Interval between Treatments	Number of Engorged Females	Number of Females Ovipositing	Average Number of Eggs	Average % of Eggs Hatching	Longevity of Resultant Larvæ
338	Very heavy	3 days	2	2	400	50	17 days
339	Light		Nil				
340	Very heavy		Nil				
341	Light	5 days	Nil				
342	Moderate		1	1	50	Nil	
343	Light		Nil				
344	Light	5 days	Nil				
345	Light		Nil				
346	Light		Nil				
347	Light	7 days	Nil				
348	Heavy		Nil				
349	Moderate		Nil				
350	Light	7 days	Nil				
351	Light		1	1	400	20	39 days
352	Heavy		2	2	200	10	43 days
353	Light	10 days	Nil				
354	Light		Nil				
355	Light		Nil				
356	Light	10 days	Nil				
357	Light		1	1	200	90	49 days
358	Light		1,832	Approximately 100 per cent viable ticks			
359	Light	Controls	666				

NOTE.—The above cattle were not all heavily infested with ticks in all stages. They mostly carried heavy infestations of young ticks up to and including engorged nymphs. Several, however, carried ticks in all stages.

No. 359 was specially selected as a control, as it appeared to be and probably was the most lightly infested animal in this group.

TABLE VIII

Arsenic 7 lb., caustic soda q s., adjuvant 3 galls Stockholm tar, 4 lb hard soap per 400 gallons

March 1928

No. of Animal	Type of Infestation	Interval between Treatments	Number of Engorged Females	Number of Females Ovipositing	Average Number of Eggs	Average % of Eggs Hatching	Longevity of Resultant Larvæ
420	Moderate	3 days	1	Nil			
421	Heavy		1	Nil			
422	Heavy		4	1	800	Nil	
423	Moderate	5 days	5	Nil			
424	Moderate		3	2	1,000	Nil	
425	Moderate		4	2	1,000	20	47 days
426	Moderate	5 days	Nil				
427	Heavy		Nil				
428	Moderate		1	Nil			
429	Heavy	7 days	1	Nil			
430	Light		5	5	2,000	75	43 days
431	Moderate		6	4	1,500	Few only	Not determined
432	Light	7 days	Nil				
433	Heavy		4	4	1,500	20	49 days
434	Heavy		42	35	1,500	70	47 days
435	Heavy	10 days	Nil				
436	Heavy		Nil				
437	Moderate		2	2	1,000	Nil	
438	Heavy	10 days	Nil				
439	Light		Nil				
440	Moderate		8,177	Approximately 100 per cent normal viable ticks			
441	Moderate	Controls	6,468				

TABLE VIII.

Arsenic 7 lb, caustic soda q s, adjuvant, emulsion contained in proprietary liquid concentrate, per 400 gallons

May 1927

No of Animal	Type of Infestation	Interval between Treatments	Number of Engorged Females	Number of Females Ovipositing	Average Number of Eggs	Average % of Eggs Hatching	Longevity of Resultant Larvae
54	Moderate	3 days	6	Nil			
55	Light		3	Nil			
56	Very heavy		18	2	600	80	51 days
57	Moderate		18	2	1,100	90	35 days
122	Very heavy		14	3	1,200	Nil	
123	Very heavy	5 days	8	6	800	Nil	
124	Very heavy		Nil				
125	Very heavy		5	2	100	Nil	
126	Very heavy		3	Nil			
67	Moderate		3	1	200	Nil	
68	Light	7 days	Nil				
69	Moderate		Nil				
70	Moderate		3	1	1,500	90	29 days
71	Heavy		Nil				
127	Very heavy		5	4	1,200	20	31 days
128	Very heavy	10 days	2	Nil			
129	Very heavy		3	2	1,500	Nil	
130	Very heavy		3	1	2,000	Nil	
131	Very heavy		3	2	1,500	Nil	
*92	Light	Controls	2,545	Approximately 100 per cent normal viable ticks (first six days only) approximately 100 per cent normal viable ticks			
93	Moderate	54 57	3,019				
94	Moderate	67 71	2,906				
*142	Very heavy	Controls	5,306				
143	Very heavy	122 131	4,621				

No counts made on 142 and 143 after sixth day

* See also Tables VIIa and VIIb

TABLE VIIa

Arsenic 6 lb, caustic soda q s, adjuvant nil, per 400 gallons

August 1927

No of Animal	Type of Infestation	Interval between Treatments	Total Engorged Females	Total Females Ovipositing	Average Number of Eggs	Average % of Eggs Hatching	Longevity of Resultant Larvae
186	Heavy	3 days	14	1	30	Nil	
187	Heavy		1	Nil			
188	Light		Nil				
189	Heavy	5 days	Nil	Nil			
190	Heavy		5				
191	Very heavy		Nil				
192	Light	7 days	Nil				
193	Heavy		Nil				
194	Heavy		Nil				
195	Very heavy	10 days	Nil				
196	Very heavy		Nil				
197	Light		Nil				
198	Heavy	Control	Nil				
199	Very heavy		Nil				
200	Light		Nil				
201	Heavy		9	Nil			
*234	Heavy		5,505	engorged females removed first ten days of stalling, after which no further counts were made, although the animal still carried many thousands of immature ticks Approximately 100 per cent normal viable females			

* This animal also acted as control for those animals shown in Tables VIIa and VIIb

TABLE VIIIn

Arsenic 6 lb, caustic soda q s, adjuvants 1½ gal Stockholm tar, 2 lb hard soap per 400 gallons

January 1928

No of Animal	Type of Infestation	Interval between Treatments	Total Engorged Females	Total Females Ovipositing	Average Number of Eggs	Average % of Eggs Hatching	Longevity of Resultant Larvæ
360	Very heavy	3 days	8	Nil	400 300	Nil Odd ones	Not determined
361	Heavy		23	Nil			
362	Very heavy		12	4			
363	Very heavy		7	3			
364	Moderate	5 days	4	Nil			
365	Light		Nil				
366	Light		Nil				
367	Moderate		Nil				
368	Heavy	7 days	Nil				
369	Heavy		Nil				
370	Very heavy		Nil				
371	Very heavy		Nil				
372	Moderate	11 days (owing to heavy rain)	Nil				
373	Heavy		Nil				
374	Heavy		1	Nil			
375	Moderate		Nil				
376	Very heavy	Controls	1	Nil	Approximately 100 per cent viable ticks		
377	Heavy		Nil				
378	Heavy		Nil				
379	Heavy		Nil				
380	Heavy	Controls	10,948				
381	Very heavy		22,768				

No counts made on controls after eighteenth day, although both animals apparently still carried a few thousand ticks. No 381 was the only animal classified as a "very heavy" infestation, which was used as a control and from which anything like an approximate estimate of the total number of ticks carried by such an animal was obtained. During the first eighteen days of stalling nearly 23,000 engorged female adults were collected. The condition of this animal was typical of many others classed as "very heavy" infestations, further there is little doubt that many of the "heavy" infestations would have yielded a number of ticks not far short of the above total, because the tendency was to classify the animals in the lower rather than in the higher category.

TABLE VIIc

Arsenic 6 lb, caustic soda q s, adjuvant 3 galls Stockholm tar, 4 lb hard soap per 400 gallons

January 1928

No of Animal	Type of Infestation	Interval between treatments	Total Engorged Females	Total Females Ovipositing	Average Number of Eggs	Average % of Eggs Hatching	Longevity of Resultant Larvæ
397	Moderate	3 days	Nil				
398	Light		Nil				
399	Light		Nil				
400	Light		Nil				
401	Light		Nil				
402	Light	5 days	Nil				
403	Light		Nil				
404	Light		Nil				
405	Moderate		Nil				
406	Heavy		Nil				
407	Very heavy	7 days	Nil				
408	Light		Nil				
409	Very heavy		Nil				
410	Light		Nil				
411	Moderate		Nil				
412	Very heavy	10 days	Nil				
413	Light		Nil				
414	Very heavy		Nil				
415	Light		Nil				
416	Heavy		Nil				
417	Light	Control	1,241	Approximately 100 per cent normal viable ticks			

No 417 (control) was specially selected as being apparently the most lightly infested animal in the group

TABLE VIIb

Arsenic 6 lb, caustic soda q s, adjuvant emulsion contained in proprietary liquid concentrate, per 400 gallons

May 1927

No of Animal	Type of Infestation	Interval between treatments	Total Engorged Females	Total Females Ovipositing	Average Number of Eggs	Average % of Eggs Hatching	Longevity of Resultant Larvæ
50	Light	3 days	4	Nil			
51	Light		4	Nil			
52	Heavy		9	2	300	90	Not determined
53	Heavy	5 days	5	Nil			
112	Very heavy		1	1	2,500	50	28 days
113	Very heavy		3	Nil			
114	Very heavy		10	Nil			
115	Very heavy		1	1	1,500	Nil	
116	Very heavy	7 days	2	1	1,000	Nil	
62	Moderate		4	1	2,000	90	43 days
63	Heavy		2	Nil			
64	Very heavy		Nil				
65	Very heavy		4	4	500	80	35 days
66	Moderate	10 days	5	3	700	Nil	
117	Very heavy		3	3	2,000	Nil	
118	Very heavy		5	3	1,200	Nil	
119	Very heavy		6	3	350	Nil	
120	Very heavy		45	30	1,200	20	3 days
92	Light	Controls	2,545	Approximately 100 per cent normal viable ticks (six days only), approximately 100 per cent normal viable ticks			
93	Moderate	50 53	3,019				
94	Moderate	62 66	2,906				
*142	Heavy	Controls	5,306				
143	Heavy	112 120	4,621				

* See also Tables VIIa and VIIc

DISCUSSION

In order to simplify the sixteen different tables set out under the experiment under discussion, we have tabulated in a brief and concise manner the whole of the results in the simple table below —

TABLE VIIq

Adjuvants per 400 gallons	Arsenic as As_2O_3 per 400 galls 6lb				Arsenic as As_2O_3 per 400 galls 7lb				Arsenic as As_2O_3 per 400 galls 8lb				Arsenic as As_2O_3 per 400 galls 9lb			
	<i>Days between Treatment</i>															
	3	5	7	10	3	5	7	10	3	5	7	10	3	5	7	10
Nil	†	†	†	†	†	†	†	†	†	†	†	†	-	†	†	-
1½ gal Stockholm tar and 2 lb hard soap	-	†	†	†	-	†	-	-	†	†	†	†	†	†	†	†
3 galls Stockholm tar and 4 lb hard soap	†	†	†	†	†	-	-	†	†	†	†	†	†	-	-	-
Emulsion contained in certain proprietary medicament	-	-	-	-	-	†	-	-	-	-	†	-	†	†	†	†

† means all ticks immediately destroyed or survivors failed to oviposit fertile eggs

- means some survivors ovipositing fertile eggs, or treatment was less than 100 per cent effective

1 The Value of Emulsion

(a) *Increasing the "tickicide" value of the dipping fluid*—One of the emulsions employed, consisting of Stockholm tar and ordinary hard soap, is almost identical with that prescribed by the New South Wales Stock Department and one of those prescribed by the Queensland Stock Department, except that such emulsion was used and tested by us in considerably greater proportions than that recommended by either department

The Queensland official dip A (see Regulations under Stock Diseases Act) contains ¼ gallon Stockholm tar and 4 lb tallow or oil, the latter being emulsified by means of caustic soda

The New South Wales official dipping fluid contains ½-1 gallon of tar and 2 lb hard soap, while washing soda is used in place of caustic soda to bring about solution of the arsenic and to emulsify the adjuvants used

In all of those countries in which the dipping of cattle for tick destruction is carried out extensively, emulsions are as a rule considered necessary to bring about maximum effectivity, and they are usually included in official dipping fluids. There seem to be some theoretical reasons why they should be added to such fluids. But in order to warrant the inclusion of an adjuvant like Stockholm tar, it would be necessary to show that such an ingredient was of more than minor importance, because even the addition of the small quantities prescribed in the official formulæ adds considerably to the cost of the medicament

Brunnich and Smith^{1,2} state that, when tallow or oil soaps and Stockholm tar are incorporated with an arsenical dipping solution extra efficiency is obtained, with the result that these or similar adjuvants are now universally used as ingredients in cattle-dipping fluids. They agree as to the absolute necessity of these substances if maximum tick-destroying effects are desired. These observers also consider that the extra efficiency is brought about as a result of a lower surface tension found in a fluid containing emulsion, this physical factor admitting of a more thorough wetting of the skin of the host and its parasite. A series of experiments were carried out by these workers, which showed that the oleic acid soaps had a higher wetting power than the ordinary stearic acid soaps of tallow, and they therefore recommend the use of the former soaps in preference to tallow soaps in the preparation of dipping fluids. "Stockholm tar soap" and resin were regarded as being of considerable efficacy. Phenolic agents they do not regard as being of any value as emulsifying agents. Increase of the amount of alkali in the Government dip formula they do not consider advisable under ordinary circumstances. They showed also, that the use of hard water leads to a marked diminution in the wetting power of a dip containing fatty acid soaps, owing to the precipitating action of the calcium and magnesium salts.

These two observers also carried out some experiments on the use of bone-oil as an adjuvant in arsenical dipping fluids, and concluded that it could be used as a substitute for tar and soap. It was preferable in some respects as it was less expensive.

Bulletin 1057 of the U.S.A. Department of Agriculture recommends the use of pine tar as an adjuvant in the preparation of arsenical dipping fluids. It is there stated that a plain solution of sodium arsenite does not make an entirely satisfactory dip and the addition of pine tar possibly "increases the wetting or spreading power of the dip bath, which probably results in better penetration and effectiveness against ticks and less risk of blistering."

Cooper and Laws³ observe that an aqueous solution of sodium arsenite must be used in considerably greater concentration than when used in conjunction with an emulsion of soap and oil in order to bring about the same destructive effect on the tick. They found that a solution of sodium arsenite containing 153 per cent As_2O_3 , plus emulsion was as efficacious as a solution containing 225 per cent As_2O_3 , without emulsion. These authors therefore regard the use of emulsions in cattle-dipping fluids as being of very great importance.

Watkins Pitchford⁴ carried out a series of observations in Natal on the effect of treating tick-infested cattle with arsenical dipping fluids. He showed that cattle could be treated at three-day intervals over long periods with an arsenical solution containing adjuvants such as soft soap and paraffin, and of sufficient strength to destroy the tick but yet produce no untoward effect on the animal host. The use of the three-day dip was recommended where East Coast fever had appeared on a farm, and

where it was essential that all ticks should be destroyed before they had completed their engorgement and dropped from the host. As the shortest period occupied by the tick in any one of its parasitic stages was approximately three days, treatments were spaced at intervals of not longer than seventy-two hours. The arsenical strength of the three-day dip was approximately 2 lb of arsenic (As_2O_3) per 400 gallons of solution, and treatment with this fluid was supplemented by hand dressing of certain parts of the body, such as inside the ears, the under surface of the butt of the tail, and the end of the tail, or brush, these three points being seats of predilection of the tick. The nymphal tick frequently entered the ear passage and penetrated as far as the tympanic membrane and was often protected by the waxy secretion from the ear-glands, while the adults found under the tail and in the brush often formed dense aggregations of parasites in the form of a thatch.

The same observer recommended the use of a five-day dip which contained approximately double the quantity of arsenic used in the three-day dip. He found that this solution, together with an emulsion of paraffin and soap, could be used over long periods without detriment to the cattle treated, while it destroyed large numbers of parasites and reduced the ticks on the pasture to a very small minimum.

This worker concluded that the use of paraffin and soap increased to a certain extent the tick-destroying powers of the arsenic.

Cohen⁸ states that the use of emulsion is not essential provided the wetting is thorough, but adds that as this cannot be ensured under ordinary field conditions he recommends its use.

Jack,¹¹ quoting Theiler, states that many farmers in South Africa use an aqueous solution of sodium arsenite and do not regard the extra expense involved by adding soft soap and paraffin to the mixture as being warranted.

Much of the work conducted in investigating the use of cattle dips has been performed in countries like South Africa, where the economic importance of the tick is considerably greater than in Australia. Moreover, the conditions in the two countries are entirely different. In South Africa efforts at eradication are directed against such ticks as *Rhipicephalus appendiculatus*, the brown tick, which is an interrupted feeder spending only a few days at a time as a parasite, while in Australia *Boophilus australis*, the common cattle tick, is a continuous feeder spending at least twenty days on its host. Hence a system of treatment which might eradicate a tick like *Boophilus australis* would be useless against a tick like *Rhipicephalus appendiculatus*. Continuous feeders like *Boophilus decoloratus*—in South Africa a tick closely allied to the *Boophilus australis*—are not considered to be of such economic importance as the interrupted feeders which convey such diseases as East Coast fever, and any system of treatment which will eradicate the interrupted feeder will also account for the continuous feeder. It is because of the importance of the interrupted feeder in South Africa that so much work

has been done with the short-period dipping fluid of high dilution, and why Watkins Pitchford and others attempted experiments designed to discover some substance, other than arsenic, not poisonous to the animal host but which increased the tick-destroying power of the arsenical fluid.

Although, therefore, there seems to be a general opinion on the question of whether an emulsion should be added to dipping fluids, so far as we know, no comparative experiments extensive enough to warrant clear-cut and definite conclusions as to the value of emulsions—taking into consideration their cost and the ease with which they can be incorporated in the arsenical solution—in increasing the “tickicide” value of cattle-dipping fluids have ever been performed in Australia.

If we now examine the table setting out the results of the animals treated in this experiment, it is fairly clear that the amount of emulsion used bore no relationship to the result. In the dipping solution containing $1\frac{1}{2}$ gallon of tar per 400 gallons solution, the whole of the ticks were destroyed at strengths of 8 and 9 lb arsenic, but failed to destroy at 6 and 7 lb arsenic. When the amount of emulsion was doubled the 6 and 8 lb dips destroyed all ticks, but the solution failed at 7 lb and again at 9 lb. On the other hand, the dipping fluid consisting of an aqueous solution of sodium arsenite destroyed all ticks at 6, 7, and 8 lb, but failed to destroy at 9 lb, a seeming paradox. The proprietary medicament failed to destroy at 6, 7, and 8 lb per 400 gallons, but destroyed all ticks when the amount of arsenic, plus a proportionate amount of emulsion, was raised to 9 lb.

Actually the evidence shows that, of all these groups of cattle treated in a solution of sodium arsenite without emulsion, a greater number of groups remained entirely clean after treatment than in the case of those groups of cattle treated in dipping solutions containing emulsions. This does not indicate that the value of the medicament as a tick-destroying agent is *decreased* by the addition of emulsion, but it does indicate that a solution of sodium arsenite without the addition of emulsion or adjuvant of any kind is a powerful tick-destroying agent so far as *Boophilus australis* is concerned, and compares very favourably with those dipping fluids tested which contained emulsions, in some cases in considerable quantities. So far as our own observations go they point to the conclusion at least that under field conditions the omission of the emulsion does not decrease in any way the tick-destroying powers of the dipping fluids tested.

(b) *As an Emollient*—Besides increasing the “tickicide” value of the dipping fluid, some observers regard the inclusion of emulsions as a necessary factor in preventing scalding and cracking of the skin.

Brunnich and Smith are of the opinion that emulsions have a decidedly beneficial and emollient effect while aqueous solutions of sodium arsenite have at times a severe local scalding action.

Watkins Pitchford regarded the use of paraffin and soft soap as an important factor in preventing cracking and scalding of the skin, and

showed that animals could withstand the short-interval treatments without detriment over longer periods when emulsions were added than when treated with an aqueous solution of sodium arsenite

The short-interval treatment, as we previously stated, so necessary in South Africa, is responsible for the cracking and scalding of the skin, whereas in Australia short-interval treatment is not required and the use of an ingredient which would prevent this untoward feature is not demanded to the same extent

During our experiments we have made careful note as to the effect of the dipping fluid on the skin of the animals, and it was impossible to distinguish between the effects of the dipping fluids containing emulsion and those containing no emulsion. Slight cracking of the skin only occurred in an odd animal even with the 9-lb dips in those cattle undergoing two treatments at seventy-two hour intervals. A reference to the tables will show that some of the cattle were treated in the stronger solutions of arsenic (8 and 9 lb) during the summer months (October and November), or over a period when the weather conditions in North Queensland are very hot and oppressive

It has always been difficult for us to conceive how the employment of an emulsion made up of tar and soap in such small quantities as laid down in the official formulae can have any beneficial or emollient effect on the skin of the host

Considering that the Queensland official formula "A" contains $\frac{1}{4}$ gallon tar to 400 gallons of solution, and that each animal takes out of a dip about 1 gallon of fluid (or $\frac{1}{800}$ gallon of tar) which is spread over the complete surface of the skin and hair, one has difficulty in understanding how such an extremely small quantity of tar and soap can be credited with beneficial properties

It is quite true that many heavily infested animals show a marked improvement in the general condition of the cutaneous tissues within a few days of treatment, but this benefit is undoubtedly due to the destruction of the tick and the healing of the tick sores

One of us (J L), after considerable field observation following the use of dipping fluids of standard strength, has been led to the belief that extensive cracking of the skin* only occurs where animals are driven considerable distances immediately or soon after treatment (next day), and this will occur even after a single treatment and irrespective of whether the particular dipping fluid contained emulsion or not. The condition is considerably aggravated during hot weather, particularly if the cattle are wild and difficult to hold

Where cattle are kept quiet and unmolested, as in our own experiments, two treatments only a few days apart even in summer, under

* The same feature may be seen in cattle entrained and travelled over long distances immediately or soon after treatment.

North Queensland conditions, produced little, if any, effect on the skin of the animals, irrespective of whether emulsion was or was not added to the dipping fluid

2 Arsenical Strength of Dipping Fluid

A comparison of the four different dips tested (that is, different in the matter of arsenical strength, viz, 6, 7, 8, and 9 lb. arsenic, as As_2O_3 , per 400 gallons) shows that there was no great difference between each group. In no case did any one of these four different dipping fluids destroy all ticks on all animals treated with two applications of the medicament.

The dipping fluid containing 6 lb arsenic per 400 gallons failed on one occasion when the emulsion consisted of $1\frac{1}{2}$ gallon tar and 2 lb hard soap per 400 gallons, and on all four occasions when the proprietary mixture was tested. The 7-lb dip failed three times when the emulsion consisted of $1\frac{1}{2}$ gallon tar and 2 lb hard soap, twice when the solution contained double this quantity of adjuvant, and three times with the proprietary dip. At 8 lb all dips were effective except the proprietary mixture, which failed three times, whilst at 9 lb two dips failed, viz, the one containing no adjuvant and that containing the maximum amount of tar and soap. The other two dips tested at 9 lb, viz, that containing the proprietary mixture and that containing the smaller quantity of tar and soap ($1\frac{1}{2}$ gallon tar and 2 lb soap), both proved effective in destroying 100 per cent of the ticks on the animals treated.

If we again examine the various tables which set out details concerning the degree of infestation of the cattle concerned, we shall notice that compared with the controls the actual number of ticks which were subject to treatment by any one of these four different dips tested was at least very many thousands. When we further examine the columns showing the actual number of ticks which survived treatment, we find that rarely did the number of such survivors exceed four or five. Even where a considerably greater number of survivors were found ovipositing (such as No. 120, Table VIIr) it will be noted that the percentage of fertile eggs was fairly low, thus showing that probably only a small percentage of surviving females contributed fertile eggs.

On the whole it can be said that, although all four dips were highly efficient, there is nothing like the margin one might expect between two treatments in a dip containing 6 lb arsenic per 400 gallons and one containing 9 lb of the same ingredient in an equal quantity of fluid. The former occasionally allows not more than an odd tick to escape even on the most grossly infested cattle, and the latter may apparently do likewise under some circumstances.

3 Interval between Treatments

As shown in the tables, the intervals allowed were 3, 5, 7, and 10 days. Practically no difference was noted between the various groups. Odd ticks appear to escape irrespective of the interval allowed. It will

be noted that a greater number of engorged ticks were usually removed where the treatments were spaced at intervals of three days, but the number of such survivors contributing fertile eggs was in reality no greater than where the intervals were larger

4 *Portions of the Body on which Survivors were Found*

If we examine the subsequent history of animals which received one treatment in an arsenical dipping fluid (as Animals Nos 511, 512, 513, and 514 in Table IVB), it is at once evident that almost the whole of the ticks in the pre-adult stage at the time of treatment are immediately arrested in their development and are ultimately destroyed. This may occur even when the arsenical content of the dip is considerably lower than the quantity laid down in the official formula (8 lb As_2O_3 per 400 gallons). Thus Table V gives the complete history of a number of cattle treated once in a dipping fluid containing only 5 lb arsenic per 400 gallons, which fluid allowed only odd ticks not in the adult stage at the time of treatment to reach maturity. This fact is, of course, well known from field observations, where we often find great difficulty in locating mature adult ticks on cattle in the second and third weeks after treatment, even if the dipping fluid at times is considerably lower in arsenical strength than that prescribed for the official dip.

Even if we introduce, immediately or soon after treatment, factors likely to strongly militate against the lethal effect of the arsenic, as by spraying with water (Table IVB), we still see that the younger ticks are largely if not wholly destroyed.

The same result is shown in Experiment 1, where we used artificially infested cattle carrying large crops of ticks all of the same parasitic age at the time of treatment. The observations there indicate that very odd ticks up to the seventeenth day of parasitic life are capable of escaping one treatment. The only ticks which survived in appreciable numbers were those which happened to be in the last three or four days of parasitic life at the time of treatment (nineteenth and twenty-first day).

On theoretical grounds, therefore, one would expect that, as a single treatment arrests the development of nearly all those ticks up to and including the young adult stage, a second treatment—placed at an interval of not less than five days, which will allow adults in the last four days of parasitic life to reach maturity and leave the animal—must destroy the very few ticks which escape the first treatment, and not only do this but leave a fair margin of safety.

Why is it, then, that ticks are found to be maturing on cattle even after two treatments in an arsenical dipping fluid containing as much as 9 lb arsenic per 400 gallons?

We have always been under the impression that the thick, heavy winter coat of a tick-infested animal, particularly if the hair is very dirty and matted together, may act as a protection to the tick beneath, and so prevent the dipping fluid from coming into contact with the parasite. We have noticed in the field that when ticks escaped two

treatments the survivors were almost wholly found on the upper portions of the neck, back, and loins, and occasionally on the outside of the leg between the patella and the hock. These represent those portions of the body on which the hair is both denser and longer. The point is all the more important because the region of the back and loins*, even in many very heavily infested cattle, relatively speaking, frequently carries a smaller number of the parasites than the region of the escutcheon and flank. In our experiments and observations we have never found ticks surviving two treatments in the region of the escutcheon and inner surface of the flank, though in large numbers of naturally infested cattle these areas are the most heavily infested parts of the body irrespective of the class of animal examined. In fact, in the observations carried out by us in this experiment (No VII) we found, that for the purposes of examination, areas of the body such as the under surface of the belly, brisket, escutcheon, and inner surface of the flank could have been entirely neglected. No survivors at any time were discovered maturing in these areas, for the ticks here are fully exposed to the application of the dipping fluid.

Where a number of ticks were found maturing on any one animal after the second treatment, in nearly all cases they were found in one or two small areas in a mass of thick, long hair, and one could not escape the conclusion that in these cases the dipping fluid failed to make contact with the tick. Animal No 482, which was treated with two applications of a medicament containing 9 lb arsenic, 3 lb Stockholm tar, &c, with an interval of ten days between treatments, yielded within a week following the second treatment nearly fifty mature female ticks, a considerable number of which oviposited fertile eggs. All of the survivors were removed from a small area in the region over the transverse lumbar processes. This animal, like all others, had been thoroughly immersed at the time of both treatments.

When these ticks were discovered the day following the second treatment their condition and appearance indicated that the dipping fluid had not affected them in any way at the time of the second treatment, and the long, dense, matted hair with which the parasites were then covered probably also protected them at the time of the first application of the medicament.

Similarly with other cattle treated the indications were that where the hair is long and matted together, as it may be by means of faeces and dirt, odd ticks may be afforded sufficient protection to allow of their complete or almost complete immunity from the effects of the dipping fluid.

* It frequently happens that with badly constructed dips, and/or with cattle injured to dipping, when complete immersion of the animal is not procured, ticks may be found maturing on such places as the top of the head and neck, or any place that has not been brought into contact with the dipping fluid.

We think the question requires more study, but the mild winter conditions in North Queensland means that very few cattle develop the heavy coats found in the more wintry parts of the State farther south, hence a good supply of suitable animals is not available to us

Conclusions—The evidence which we have gathered points to the following conclusions —

1 No two treatments at intervals of three to ten days, in a medication containing up to 9 lb of arsenic (As_2O_3) per 400 gallons of fluid, can be relied upon to destroy all ticks in all stages on an infested animal.

2 The omission of Stockholm tar and soap from the dipping fluid does not interfere with the efficacy of the solution as a tick-destroying agency

3 Two treatments in a solution containing 6 lb arsenic as As_2O_3 per 400 gallons is, under field conditions, as efficacious as two treatments in a solution containing up to 9 lb of arsenic in an equal quantity of fluid

4 When fertile survivors are found after the second of two treatments in a solution containing 6 lb or more of arsenic per 400 gallons, they occur under circumstances which indicate that the dipping fluid has failed to make proper contact with them

SUMMARY

The experimental evidence which we have been able to bring forward in the various experiments under review points to the following conclusions —

The tick is more resistant to treatment with arsenical dipping fluids during the last three or four days of parasitic life. The point is of importance in any system of tick eradication, in that treatments must be so spaced as to prevent as far as possible any tick from reaching the resistant stage

The application of arsenical dipping fluids prevents reinfestation for twenty-four hours after treatment but not for forty-eight hours

If cattle are allowed to enter water immediately after treatment and remain therein for considerable periods, the efficacy of the treatment is interfered with to a considerable extent

Light showers do not seriously interfere with treatment, provided rain does not fall within an hour after treatment and the animals are allowed time to dry

Retention of the animals in the vat—within reasonable limits—or increasing the length of the vat does not influence the effect of the dipping fluid on the tick

Alteration in the physical character of the fluid, such as is brought about by prolonged use, does not interfere with the efficacy of the solution as a tick-destroying agency

No two treatments with an arsenical dipping fluid containing up to 9 lb of arsenic as As_2O_3 per 400 gallons can be relied upon to destroy all ticks on an infested animal

The omission of the emulsion of tar and soap from the official dipping fluid does not lessen the efficacy of the solution

Ticks may be protected from treatment by the long, dense hair which occurs particularly in the winter time on many cattle

Finally we might add that, although the evidence we have been able to bring forward in the above experiments helps to throw light on some of the more important points which arise when the question of tick suppression is under consideration, there are other equally important points on which evidence is also necessary before one is able to fully appreciate the difficulties presented by the problem of tick eradication under Australian conditions

Much more work is required on the use of emulsions in dipping fluids. As the dipping fluid containing 6 lb arsenic per 400 gallons was as efficacious under ordinary conditions as the standard fluid (8 lb) it is not improbable that still higher dilutions could be used with equally good effects

It appears to us that the more frequent use of dips of high dilution may prove a more efficacious method of bringing about tick suppression than the less frequent use of fluids containing larger quantities of arsenic. It certainly offers a valuable field for further research

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Some Observations on the Life History of the Cattle Tick (*Boophilus australis*).*

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(Communicated by Mr. F. A. Perkins, B Sc Agr, to the Royal Society of Queensland, 29th July, 1929)

The history of the cattle tick in Queensland shows that it entered the State from the Northern Territory at its extreme north-western corner about 1891, and from this point made little headway for the first couple of years. After the closure of the meatworks at Normanton the parasite moved rapidly south and east, its spread being greatly facilitated through movements of cattle by rail.

In 1896 the tick reached Hughenden, and before the end of the same year it had extended as far as Rockhampton. In 1899 Brisbane was reached, but owing to its slower progress south of that city to the border of the State the tick did not appear in New South Wales until 1906.

At present the parasite has established itself over all that area of Queensland where climatic and other conditions are suitable for its propagation, the line of demarcation between the infested and non-infested area being represented roughly by the watershed of the coastal rivers. Between these areas there lies a strip of country where the presence of the tick is discontinuous. In dry seasons this strip is non-infested, after a series of wet years it is liable to become infested.

The losses due to the tick are twofold. It acts as the vector in transmitting piroplasmiasis (*P. bigeminum*), a disease which has caused very heavy losses in cattle in Queensland in years gone by, and even to-day is a serious obstacle in the transfer of non-immune cattle to infested areas, but apart altogether from its association with piroplasmiasis it is undoubtedly an important pest of cattle, producing anaemia, tick worry, &c., and is a definite handicap to the development of the cattle industry in Queensland.

In view of these circumstances it is very important that a full and complete knowledge of the life history of the tick should be gained.

The cattle tick of Australia falls into the class of what are known as continuous feeders, that is, they pass through the whole of their parasitic life attached to the one host.

Preoviposition—The female adult tick does not commence to oviposit immediately after reaching repletion and detachment from the host. This period between detachment and the commencement of oviposition is known as the preoviposition period, and during this period the tick

* An extract and a summary of a Paper bearing the same title, and which formed part of a thesis for the Degree of Doctor of Veterinary Science in the University of Melbourne.

usually hides beneath grass, debris, leaves, wood, &c. A series of observations showed that the period was influenced by the season of the year, and varied from a minimum of two days in summer to twelve days in winter. Roughly the periods are five to nine days in winter, four to six days in spring and autumn, and two to four days in summer.

Oviposition, or the period occupied in producing eggs, varies also according to the season of the year. The differences between the summer and winter variations were not very great. In summer, however, once ovipositing commences the majority of eggs are laid during the first week, and there is a marked tendency for ovipositing to cease abruptly, to be soon followed by the death of the tick, while during winter there is usually a gradual slackening-off of the process. The shortest period of ovipositing was five days (summer) and the longest thirty days (winter).

Egg Stage—The egg is elliptical, dark brown in colour, and covered with an albuminous-like secretion.

Altogether 120 females were tested, and it was found that the average number of eggs per female was 2,579, the maximum being 4,269, the minimum 1,673. The greatest number of eggs laid by any one female during a 24-hour period was 731.

Incubation Period—This varies considerably according to the season of the year. A very large number of eggs were tested out between the months of November and July, and it was found that the minimum period was fifteen days (summer) and the maximum fifty-five days (winter). These figures were obtained at Townsville, where the average winter temperature is considerably higher than some of the tick-infested areas further south, so that probably the maximum figure would be higher still in southern Queensland, or even in the higher altitudes of the North.

The fertility of masses of eggs, selected indiscriminately, was found to be very high. During six months 127 batches were tested, and of these fifty-seven showed a fertility of over 90 per cent, fifty showed a fertility of between 80 and 90 per cent, while the lowest fertility percentage noted was 68.

The above recorded figures covering the non-parasitic life of the tick indicate why such an enormous increase in parasites takes place during a normal wet season on the Queensland coast.

Influence of Immersion in Water on Egg Fertility—Although moisture is essential to the incubation of the egg, excess of moisture, such as may occur during the submergence of large areas of land for longer or shorter periods during the wet season, might be detrimental.

Batches of eggs were tested over a period of six months. These batches were allowed to incubate for definite periods, and then split up into a series of different groups, and each group submerged for a definite period varying from one to fourteen days.

As a result of these experiments it was found that submergence for twenty-four hours at any time during the incubation period had

little effect on the fertility and ultimate development of the egg. Nearly all batches submerged for seventy-two hours showed some fertile eggs, the number varying from 3 to 89 per cent.

Seven days' submergence completely destroyed several batches, though the fertility of some groups of eggs was as high as 72 per cent.

Ten days' submergence destroyed all groups but seven, but even after such prolonged immersion one group of eggs showed a fertility of 81 per cent.

Fourteen days' submergence destroyed all eggs but one group, which showed a fertility of 12 per cent.

Otherwise the observations showed that the younger the egg the more resistant it was to immersion, while the incubation period was not affected.

The flooding of pastures therefore is not likely to have a serious effect on the eggs of the tick. In fact, flooded streams possibly assist in the distribution of the parasite from one area to another.

Effect of Sunlight on the Egg—Direct sunlight was found to have a very injurious effect upon the egg. A series of observations, somewhat along the same lines as those performed to test the effect of excess of moisture, were carried out.

Several batches of eggs were obtained and allowed to incubate for definite periods, and then exposed to direct sunlight for a short period of from one to ten hours, the observations being carried out over the first six months of 1927.

The results showed that the effect of direct sunlight for even one hour at any time during the incubation period completely destroyed many batches tested. On cloudy days, where the sun was largely obscured, odd batches withstood four hours' exposure, but the fertility was considerably reduced.

These results show the beneficial effect of shade on the developing egg, and help to explain why the tick has never been able to definitely establish itself on the open downs of Northern and Central Queensland and the Barkly Tableland of the Northern Territory.

The Larval Tick—The young larva is very minute, extremely active, possesses six legs, and stigmatal plates between the second and third row of coxae. Under natural conditions they swarm over the herbage and occasionally collect in masses together, particularly on the shady side of blades of grass, &c., moving round during the day with the sun.

It is remarkable how these masses of larvæ detect a moving body in their vicinity and show the greatest activity when disturbed. They frequently hang on by their posterior limbs and wave the anterior in the air, this procedure facilitating their prospects of attachment to a passing host.

The maximum longevity of these larvæ is a point of very great importance, as on it depends some of the methods of eradication, such as pasture rotation, &c. A series of observations extending over fourteen

months were carried out with a view to determining this point. In one series of experiments batches of larvæ, each of which consisted of several hundred individuals hatched during a single 24-hour period, were isolated in the laboratory under circumstances which prevented their escape. Some of these batches were supplied with an abundance of water, some received none, other batches were wholly shaded, some partly shaded, and some fully exposed to the sun. As the maximum longevity was set down as the period between hatching and the day on which the last larvæ was seen alive, it was possible—as there were 150 batches tested altogether—to arrive at some definite data concerning larval longevity.

The maximum longevity noted was 154 days, approximately five months, this occurring in a batch of ticks hatched in the winter, and which were shaded during the whole of the time and supplied with an abundance of moisture. Fifteen batches showed a maximum longevity of 100 days upwards, while the majority of the remainder showed a maximum longevity of between sixty and ninety days.

It was noted that with many batches all the larvæ remained alive and active for at least two months before mortality set in.

A second series of experiments were carried out in the open air by isolating small patches of grass and placing newly hatched larvæ on these patches. Moisture was provided throughout the experiment in order to keep the patches as fresh and green as possible.

Altogether forty-four batches of ticks were tested in this manner. The minimum time occupied in any one batch between hatching and the death of all larvæ was sixty-five days, the maximum 112 days.

Maximum Non-Parasitic Periods.—The maximum non-parasitic periods noted during the various recorded observations were as follows:—

Preoviposition	12 days
Oviposition	30 days
Incubation	55 days
Longevity of larva	154 days

The above figures, it is considered, are of considerable importance from the point of view of tick eradication. It is possible that the figures may be slightly increased in the cooler infested portions of the State, but for the greater portion of the infested area of Queensland the above figures would, we think, be found to hold good.

Seasonal Factors Influencing the Non-Parasitic Life of the Tick.—The increase in the number of ticks during a normal wet season in Queensland may be enormous. This is due to several factors. Heavy rain which is the general rule provides an abundance of moisture, the long grass provides adequate shade, while the excessive heat shortens the incubation period of the egg to a minimum. The non-parasitic life cycle may thus be completed in less than three weeks.

On the other hand the cold, dry winters are adverse to the propagation of the parasite. No rain falls over lengthy periods, and particularly in heavily stocked country the grass is eaten out and little shade may be

provided for the ovipositing female. The cold weather necessitates a lengthy incubation period of the egg, which means that its chances of survival are considerably lessened.

This accounts for the inability of the tick to definitely establish itself over the downy country of Central Queensland, and for the fact that in a series of drought years the parasites may completely die out over extensive areas of country. In drought years, when a heavy mortality occurs amongst the cattle population, the reduction in the number of possible hosts is also a factor in determining the disappearance of the pest.

Parasitic Period—In order to obtain information on the parasitic life of the tick, a series of clean animals were infested artificially. After infestation all these cattle were allowed grazing under circumstances which precluded the possibility of natural infestation, and were only placed in stalls just before the first females reached repletion.

The cattle used were of both sexes and aged from one to three years. Some of them, having been bred on clean country, had never been previously infested with ticks, others had been subject to more or less heavy natural infestation from the time of birth and were only cleansed a few weeks before being brought to experiment. Altogether fourteen animals were infested during the summer and nine during the winter.

1 *Larval Stage*—Twenty-four hours after placing larval ticks on an animal, they will be found to have distributed themselves over the body surface, to have selected their point of attachment, and commenced to engorge. A marked predilection is noted for certain parts of the body with most animals, the most heavily infested areas comprising the flank, inguinal region and escutcheon, the neck and brisket. A tiny acroelar spot marks the point of attachment of the tick, but there is practically no exudate from the skin.

At seventy-two hours the tick has visibly increased in size, changed to a paler colour which renders it more difficult to see, especially among the lighter coloured hairs of the flank and escutcheon.

At the end of the fifth day engorgement is complete with many larvæ, and if removed from the host and placed in the laboratory at this time nymphs can usually be moulted out from most of the ticks.

During the sixth day nymphs begin to appear on many animals, the end of the seventh day sees most of the parasites in the nymphal state, though odd engorged larvæ may be present during the eighth and ninth days.

2. *Nymphal Stage*—The nymphal tick emerges from the larval integument through the latter splitting along its sides and permitting the escape of the nymph.

Apparently the nymphal tick almost immediately reattaches itself at or close to the original point of attachment. In odd cases only were we able to find completely unattached newly hatched nymphs.

Engorgement of the nymph is rapid, and is frequently completed by the twelfth day of parasitism Tidswell¹ records the presence of adults during the twelfth day, but we have not been able to observe them as early as this.

By the twelfth day, however, most of the ticks can be divided into two groups—one of larger and one of smaller nymphs. The numbers of each are about equal, and by weight the smaller nymph is about half the size of the larger. The small nymphs represent the male adults, the larger the females.

The nymphs which ultimately produce male adults commence to moult as a rule a few hours before the nymphs which give rise to females. Thus during the thirteenth day young female adults are comparatively rare, but on several animals a number of young male adults were found.

During the fourteenth, fifteenth, and sixteenth days large numbers of nymphs pass through the moulting stage and produce adults. Figures vary somewhat according to the animal examined, and to a certain extent with the climatic conditions prevailing, but examinations of a number of animals and covering both winter and summer shows that approximately 12 per cent of nymphs have moulted by the end of the fourteenth day, 50 per cent by the end of the fifteenth day, 75 per cent by the end of the sixteenth day, 90 per cent by the end of the seventeenth day. Odd engorged nymphs may be present on some animals as late as the twenty-first day.

The details covering the development of the tick are shown in the following table—

TABLE SHOWING THE DEVELOPMENT OF THE TICK DURING ITS PARASITIC LIFE

No. of Animals	Day first larvae mounted	Day last larvae moulted	Day first nymph mounted	Day last nymph moulted	ADULTS DROPPED		Minimum parasitic period Female adults (Days)	Total Engorged females	Month infected
					First day	Last day			
1	7th	10th	14th	19th	22	32	8	13	December
2	7th	9th	14th	20th	21	31	7	29	December
3	7th	9th	14th	20th	22	28	8	53	December
4	7th	9th	14th	19th	20	28	6	93	December
5	8th	8th	14th	19th	20	28	8	4	December
6	7th	8th	14th	20th	22	28	8	11	December
7	7th	9th	15th	20th	25	34	10	16	December
8	6th	8th	13th	18th	21	33	8	682	January
9	7th	8th	13th	17th	21	28	8	377	January
10	6th	8th	13th	17th	21	34	8	1,370	January
11	6th	8th	13th	17th	20	32	7	1,009	January
12	6th	9th	13th	17th	20	32	7	2,377	January
13	6th	8th	14th	17th	21	28	7	394	January
14	6th	8th	13th	18th	21	34	8	1,839	January
15	7th	9th	13th	20th	20	35	7	511	May
16	6th	9th	13th	20th	20	31	7	515	May
17	7th	10th	13th	20th	23	31	10	39	July
18	7th	10th	14th	20th	21	30	7	2,388	August
19	7th	10th	14th	20th	21	32	7	2,976	August
20	6th	10th	13th	20th	21	31	8	2,743	August
21	6th	10th	14th	21st	21	30	7	1,944	August
22	7th	10th	14th	21st	21	27	7	67	August
23	6th	10th	10th	21st	21	31	7	1,823	August

3 *Lesions Produced by the Nymph*—The bite of the nymph is followed by a reaction. This is in marked contrast to the bite of the larva, which apparently produces nothing more than a tiny erythematous patch on the surface of the skin, in the centre of which the rostrum of the larvæ is inserted. In all our experimental cattle the appearance of the nymphal tick was followed during the next twenty-four hours by considerable swellings on the surface of the body. The size of these swellings varies and depends on whether they are produced by one or several nymphs. When produced by a single nymph they are circular in appearance and measure up to an inch across, but when large numbers of nymphs, especially when several hundreds are all in close proximity, the swellings may merge into quite large urticarial-like elevations. The centre of the swelling, which corresponds to the point of attachment of the nymph, may be raised as much as a quarter of an inch above the surrounding skin, but the edges are not well defined, and gradually merge into the surrounding tissues.

These swellings appear rapidly, remain for about forty-eight hours, and just as rapidly disappear. There is no doubt that they were much more conspicuous in our experimental cattle as compared with cattle naturally infested, because with the former we were dealing with the appearance in some cases of many thousands of nymphs all hatching over a very short period, while with naturally infested cattle under ordinary circumstances the appearance of the nymphs would correspond roughly to the rate at which the larvæ were being picked up in the field.

On subsidence the swellings in many cases are followed by the appearance of a serous exudate around the point of attachment of the nymph. Necrosis of a small area of skin frequently follows with the formation of a tiny ulcer. The coagulated exudate may completely hide the nymphal tick, which does not seem to be in any way inconvenienced. In animals which are possibly a little more sensitive to the bite of the nymph, the area of the ulcer may be many times the size of the nymph itself.

Infection easily follows, and where considerable numbers of nymphs are close together the small ulcers produced may coalesce, and in this way the typical tick-sore is produced. The opinion has been formed as a result of observation of the results following the bite of the nymph that it is the nymph alone which is mainly responsible for the production of "tick-sore" and for the "lumpy" condition of the skin in naturally infested cattle.

4 *Adult Stage*—The nymphal integument splits longitudinally and the young adult emerges. The female usually reattaches at once at the same point or else in close proximity to its original position. The male ticks, however, do not reattach, but pursue their functions in searching out the unfertilised female. Some of them will be found to have located themselves beneath the larger nymphs which produce female adults, thus showing an ability to select the female really before actual moulting has occurred.

During the first three or four days of attachment the increase in size of the female is not very great. Frequently she reaches a stage of engorgement approximately three or four times that of the unengorged state, and appears to remain so for a couple of days. It is probably at this period that fertilisation really becomes effective, because, soon after, a rapid increase in size may take place, to be followed by the final engorgement occupying only a few hours, and during which there is a relatively enormous increase in the size of the parasite.

In any attempt to collect all the engorged females from a heavily infested animal, examinations have to be carried out every few hours or many ticks will be lost.

The minimum period of parasitism of the female adult is set down as six days, the average female taking usually a day or two longer.

The first engorged females complete their parasitic life history at some time during the twentieth day. A few females in the summer time were noticed to have almost completed their engorgement by the end of the nineteenth day, but none were actually fully replete till a short time later.

The number of engorged females removed and the days on which removed are shown as follows —

Day after Infestation	SUMMER		Total	Winter
	January	February		
20th	5	25	30	52
21st	13	1,344	1,357	878
22nd	60	2,493	2,553	1,538
23rd	62	1,743	1,805	2,391
24th	43	634	677	3,202
25th	25	154	179	3,078
26th	10	83	93	2,356
27th	14	43	57	1,426
28th	12	33	45	794
29th	5	10	15	151
30th	2	6	8	37
31st	2	7	9	15
32nd	1	7	8	17
33rd	0	2	2	5
34th	3	4	7	3
35th	0	0	0	1
	257	6,588	6,845	15,944

In the case of the summer observations it will be noted that the maximum number of adults dropping off was reached on the twenty-second day, in winter the maximum number was attained on the twenty-fourth day.

The male ticks evidently disappear about the same time as the females, because after the disappearance of the latter, even in heavy infestations, it is difficult to obtain males. In one observation we found males still present on the forty-sixth day after infestation, the last female having dropped on the twenty-ninth day. It is therefore possible that under natural conditions a single male may fertilise several females.

As a result of observations made on cattle which were infested with a few ticks, all widely scattered over the surface of the body, the conclusion was drawn that the female adult possibly fails to reach a state of repletion if not fertilised by the male. Attempts to thoroughly test the question by removing fully engorged nymphs from infested cattle and permitting them to moult in the laboratory and then inducing the young female adults to attach themselves to a clean host proved abortive. None of the young females could be induced to reattach to a fresh host.

The comparative sizes of the tick at different stages of its parasitic life were determined by gathering parasites of definite ages and ascertaining the number required to make one gram.

Details are given below—

Stage of Life History	Approximate number weighing 1 gram
Egg	25,000
Larvæ (unengorged)	50,000
Larvæ (engorged three days)	11,500
Larvæ (engorged five days)	6,000
Nymph (unengorged)	8,000
Nymph (small, fully engorged)	1,200
Nymph (large, fully engorged)	650
Female adult (unengorged)	780
Female adult (engorged)	47

This table shows that seventy-two hours after attachment the tick is already four times its original size (by weight), and by the end of the fifth day eight times as large.

The unengorged nymph is somewhat lighter than the engorged larvæ, similarly the unengorged female adult is lighter than the engorged nymph from which it arises.

The smaller engorged nymphs, or those which give rise to male adults, are about half the size of the larger nymphs which produce female adults.

Little difference between the periods occupied during the summer and winter by the tick in the different stages of its parasitic life history was observed. In summer the ticks develop on the whole a little more rapidly than in winter. The total period of parasitism of the tick in summer averages twenty-two days, in winter twenty-four days. The maximum period occupied by any one tick was thirty-five days.

Heavy infestations develop slightly quicker than light ones, while ticks develop just as rapidly on those portions of the skin which are thick as on the lighter and thinner areas.

Neither age, sex, nor previous freedom from the parasites had any influence on the development of the ticks. Cattle heavily infested all their lives and cleansed just before being brought on to experiment presented no difference from animals which had never been previously subject to infestation, whether natural or otherwise.

Factors Influencing the Parasitic Life of the Tick—An important feature noted in all the experiments designed to obtain information covering the parasitic life of the tick was that only quite a small percentage of the larval ticks which were used for infestation ever developed and reached maturity. This was observed with all cattle each and every time they were infested. The absence of dead ticks in a partly developed state indicated that the ticks die before attachment or else soon after, and before they begin to engorge and develop. Dead larval ticks can be found, but they are very hard to locate. Of course, owing to their size they could be present in large numbers and still be difficult to locate. American observers have also recorded the same feature, and state that the ration received had considerable influence on the development of the parasite. In our own observations cattle grazed under natural conditions presented no difference from cattle stall-fed during the whole of the parasitic life of the tick. Alterations in the rations of the stall-fed cattle made no apparent difference in the result.

We were able to test out the resistance of some very poor cattle in the drought of 1926, and found a very high mortality amongst the larvae used for infestation. A year later, in 1927, the same cattle but in much better condition showed a similar resistance.

Summing up, the conclusion was reached that neither the condition of the host nor the ration received had any influence on the development of the parasite.

The question of tick resistance, in the sense that but a small percentage of viable larvae placed on any animal ever reach maturity, leads to the further question of tick resistance and tick immunity.

Tick Habituation and Immunity—This question of tick immunity has been acutely debated in Queensland at different times, particularly because of claims which have been made to the effect that such resistance, known to occur in a very marked form in some animals, could be transferred from one animal to another by artificial means.

It is known that many ticks inject a toxin into the host, and there is some evidence to show that, with some ticks at least, recovery from the effect of the toxin leaves behind a fairly solid immunity. Thus with *Ixodes holocyclus* it is generally held that a recovery from the effects of the bite of the adult is followed by a strong resistance.

With *Boophilus australis* the evidence concerning the production of a toxin is provided by the swellings that occur after the attachment of the nymphal tick. These swellings are quite characteristic and are just as evident in cattle after years of infestation as with cattle infested for the first time.

Many cattle, however, show a resistance practically from birth—particularly certain breeds. An animal with a strain of Brahmin is usually more resistant, while our experience has led us to the belief that many Jerseys and Friesians are also highly resistant. Odd animals of any breed may be found to be carrying but few developing parasites, although running on obviously heavily infested pasture.

Our own observations on the question of tick resistance and tick immunity led to the following conclusions.—

1 That all animals display considerable resistance to the tick in the sense that only a small percentage of larval ticks—apparently quite viable when placed on the animal—ever reach maturity

2 That the mortality occurs before the larval ticks attach, or else soon after

3 That many cattle appear to possess this quality of resistance when infested for the first time

4 That the bite of the nymph in many cases is followed by a transient swelling, and this swelling is probably due to the injection of a toxin

5 That prolonged exposure to the tick rarely appears to increase the animal's resistance

Host Relationship—Although a fairly strict parasite of cattle, the pest does not confine itself to the one host. Occasionally single horses will become heavily infested with developing ticks, while others exposed to an apparently equal degree of infestation are but slightly affected. The reason is difficult to obtain. Sheep weakened by drought conditions are frequently heavily infested with ticks.

Ticks have not been observed to develop on any native animal or bird.

The infrequency under ordinary circumstances with which ticks attach themselves to any other host than cattle is a point of great importance in any system of tick eradication.

Natural Enemies—Unfortunately, perhaps, the tick in Australia appears to have but few natural enemies.

The willie-wag-tail (*Rhipidura motacilloides*) appears to be one of the most formidable enemies of the tick, but it is not a very common bird in parts of Queensland.

The crow frequently assists, while domestic poultry help to destroy female adults on the ordinary house cow.

Conclusions—The above observations have all been set down because of the paucity of literature on the subject in Australia, in spite of the seriousness of the parasite.

They show that there are some slight differences between the life history of the tick in Australia as compared with America, these variations can probably be accounted for by diversity of climate.

The tick has tended for years to establish itself in Australia everywhere where conditions are favourable, and it is probably only being arrested in New South Wales by vigorous counter measures.

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A Record of Devonian Rhyolites in Queensland.

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One Text-figure.

(Read before the Royal Society of Queensland, 29th July, 1929)

The purpose of this communication is to review the existing evidence of Devonian rhyolites in Queensland and to place on record several other extensive rhyolitic series discovered by one or other of the authors within the last few years

(A) PREVIOUSLY KNOWN LOCALITIES

1 E C Saint-Smith¹ in 1922 described rhyolites from two localities within the Kangaroo Hills mining fields, and assigned both occurrences to the Devonian period. The first of these (a series of spherulitic rhyolites from the Clarke River area, near Wando Vale) was found to lie unconformably below a sandstone series containing *Lepidodendron*, which latter was referred to the Lower Carboniferous period. The series containing these spherulitic rhyolites can be traced towards Oaky Creek, where "they are seen to pass suddenly into highly metamorphosed quartzites, slates, limestones, tuffs, &c.," with which are interbedded rhyolites, spherulitic in part. These "Kangaroo Hills formations" are stated by Saint-Smith to overlie the limestones at Burdekin Downs which the contained fossils prove to be of Middle Devonian age. Saint-Smith concludes—"It is therefore reasonable to assume that the Kangaroo Hills Series [including the rhyolites] must, for the present, be assigned to an Upper Devonian age."

2 H I Jensen², in summarising the geology of the Mount Coolon area, states—"The highly metamorphosed and steeply inclined garnetiferous quartzites and schists, probably early Devonian, were followed by late Devonian dacite eruptions and later rhyolitic eruptions." He further states that "The rhyolites range from almost aphanitic glassy varieties to coarse porphyries."

(B) NEW LOCALITIES

3 In May 1928, Bryan, while investigating the sedimentary series a few miles to the west of Herberton, came on an extensive development of beautifully banded rhyolites and interbedded rhyolitic tuffs and agglomerates. The associated sedimentary rocks were fine-grained sandstones, micaceous sandstones, siliceous greywackes, conglomerates, quartzites, shales, and cherty shales. The strike varied between N and N.W. The thickness of the rhyolites and rhyolitic tuffs is estimated as at least 2,000 feet.

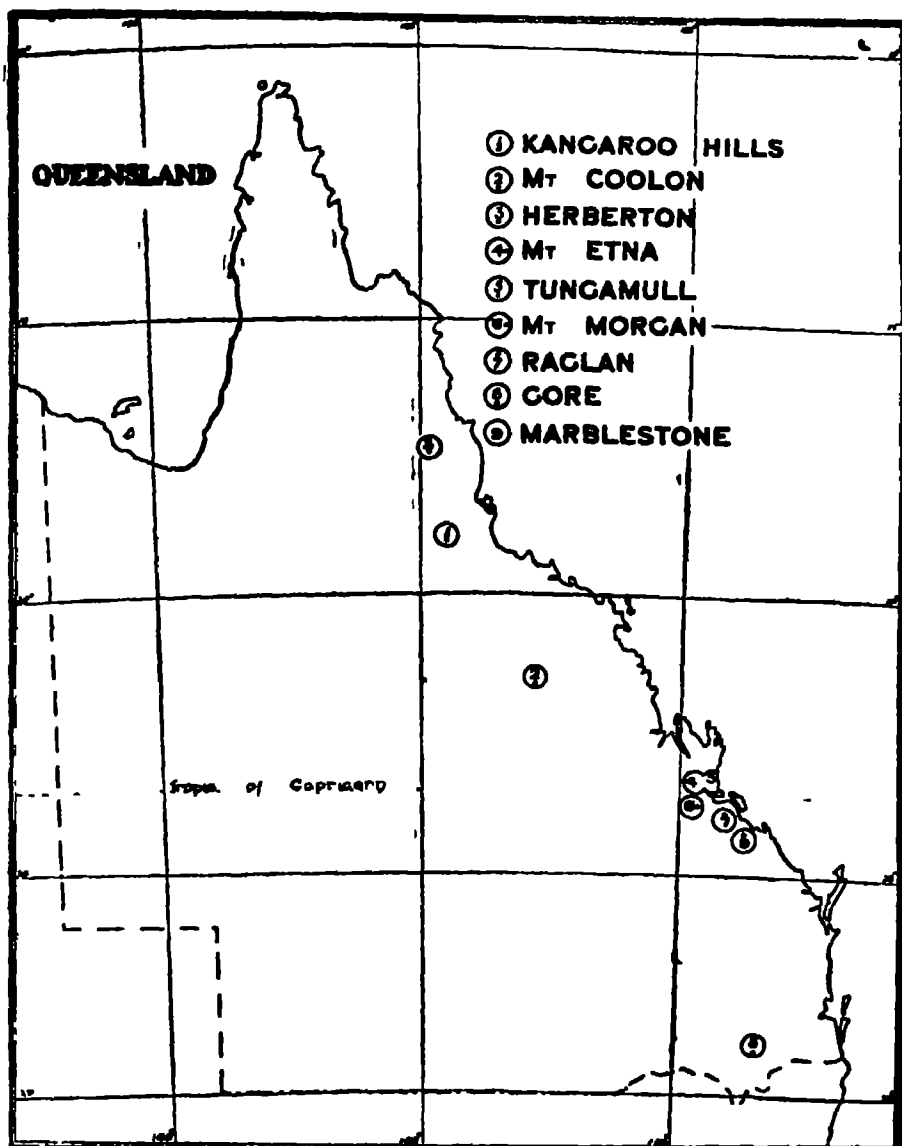
The age of the series containing the rhyolites is uncertain, but it forms part of that extensive area of metalliferous sediments to which Jack⁴ gave the name Hodgkinson Beds, assigning them to the Devonian period partly on palaeontological evidence. In the Newellton district, to the west of the area in which the rhyolites were found, Stirling⁴ reported and described a younger non-metalliferous series containing *Rhacopteris* lying unconformably above rocks of Jack's Hodgkinson Series. The rhyolites are therefore pre-Carboniferous, and it seems reasonable to assign them to the Devonian period.

4 In 1926 Whitehouse found, in the district around Mount Etna, about 15 miles north-west of Rockhampton, an extensive Devonian series of rhyolites and rhyolitic tuffs with interbedded limestones, shales, and radiolarian cherts. These deposits recently were recorded by him under the name of the "Etna Series." Serpentine of Devonian or Carboniferous age, belonging to the Great Serpentine Belt of Eastern Australia, have intruded these beds, while at a later period there have been extensive intrusions of basic and sub-basic rocks in the form of small bosses and numerous associated sills. Limestones in this area were recorded by Jack⁴, Rands⁷, and Ball⁸, while Rands also found Devonian corals. The rhyolites, however, seem to have escaped attention, although the "silicified shales" of Mount Etna mentioned by Rands really represent these rocks. In Rands's report the surrounding rocks were recorded as Permo-Carboniferous. This error was due to a mistaken identification of a frondescent *Favosites* as a species of *Stenopora*.

The series in the Mount Etna district has an average strike of about 80° west of north, and dips uniformly to the south at about 30°. The beds were traced in a north-south direction for 6 miles. Their extension further north has not yet been traced, while to the south they disappear under deposits of alluvium. Still further to the south at the mouth of Etna Creek they reappear. At this locality, however, the beds strike N W and are almost vertical, the dips being to the N E. They are very highly sheared and altered, suggesting the proximity of a fault and, possibly, also that they represent the southern limb of a syncline.

On these figures, assuming there has been no strike faulting, the minimum thickness of the series would appear to be about 15,000 feet, massive rhyolites, often with fluxion structure, forming the dominant rock type. Numerous limestone lenses have been found, some of them of very considerable thickness. Species of *Atrypa*, *Spirifer*, *Actinostroma*, *Favosites*, *Alveolites*, *Latophyllum*, *Helolites*, "*Cyathophyllum*," *Phillipsastrea*, and the peculiar tryplasmid form, previously recorded from Silverwood by Richards and Bryan⁹, have been found in these lenses. The question of the precise position within the Devonian indicated by the fossils is, however, left for discussion in a further paper.

To the east and west these beds were traced for considerable distances where, on each side, they passed under alluvium (near Yaamba on the west and Mount Hedlow on the east).



5 In more recent years the same author (F W W) has found the rhyolites of the Etna Series in other parts of Central Queensland. In the railway section from Tungamull to Nankin Junction, on the Emu Park railway line, similar rhyolites* appear, following upon the Emu Park phyllites. The relationship of the phyllites to the Etna Series has not been observed in the field, but since the lower shale beds in the Etna Series in this area are themselves phyllitic, the relationships are probably

*These rocks lie to the east of the alluvial deposits of Mount Hedlow, and probably represent a continuation of the Etna Series, which were found to disappear to the west beneath this alluvium.

conformable On the eastern slopes of Mount Shepner the rhyolites of the Etna Series were seen to be followed conformably by a great thickness of andesitic tuffs and agglomerates These tuffs are typically developed at Mount Berserker No limestones have yet been seen in this section

6 In the Mount Morgan district there is a great development of rocks of the Etna Series, particularly to the south of Mount Morgan, in the south-westerly portion of the parish of Plews In that parish the rocks again are typical rhyolites with interbedded limestone lenses No fossils, other than crinoid stems, have been found in the limestones The well-known "porphyries" and "ribbon jaspers" of the mining area of Mount Morgan* appear to be typical rhyolites of this series intruded by the granite which forms the country rock around the town

In the parish of Plews the Etna Series strikes N N.W, dipping at about 25° to the E N E Conformably succeeding this series is a vast thickness of andesitic tuffs and agglomerates† Although generally like the series at Mount Berserker, the beds in the parish of Plews include conglomerates, with well-worn pebbles up to 2 ft in diameter set in a matrix of andesitic tuff They also contain limestone lenses with an abundant Devonian fauna of corals, stromatoporoids and brachiopods

The lower portion of the Etna Series has not been observed anywhere in this area To the east the beds have been folded into a syncline, the centre of which is occupied by the fossiliferous andesitic agglomerates

7 The Etna Series reappears along the main railway line between Rockhampton and Raglan, where the beds strike N N W and dip to the S W In this region rhyolitic tuffs appear to be more abundant than rhyolite flows Limestone lenses are numerous and very large, and the well-known fossiliferous limestones of Marmor and Raglan are within this series At Raglan, the most westerly locality where the Etna Series has been traced, the lower shale beds are phyllitic like those of Tungamull, while still further to the west, phyllites of the Emu Park Series are found As at Tungamull, the field relationships of the two series have not yet been investigated, while the developments further to the south are not known

8 Recently, Bryan has had the opportunity, through the courtesy of Mr R C Hamilton of Warwick and of Mr J D Gibson of Hunter's Hill, of inspecting an area in Portion 4v, parish of Moynalty, some 7 miles south-east of Gore, in Southern Queensland In this locality a thickness of several thousand feet of chertified rocks was examined The origin and true nature of these cherts was obscure until there were discovered on several horizons excellent examples of spherulitic rhyolites.

* See, particularly, G S Hart's paper "Further Notes on the Geology of Mount Morgan," Aust Inst Mining Eng, N S, No 6, 1912, p 3 This little known paper is a very valuable account of the geology of the area.

† These form the so-called "Carboniferous andesites" of the Mount Morgan district.

The rhyolites were themselves chertified, but the nature of the weathered surfaces left no doubt as to their origin. It would seem reasonable to suppose that the whole series of cherts was largely, if not entirely, formed from the alteration of flows of rhyolite, and the absence of the stratification characteristic of cherts formed by the silicification of shales or other sediments certainly supports such a supposition. The age of the rhyolites is far from certain, but they appear to overlie a series of limestones and massive red jaspers similar to those which have in other parts of Queensland been assigned to the Lower Devonian. In these circumstances they may be regarded tentatively as of Devonian age.

GENERAL REMARKS

During the past few years, Susasmilh¹¹ and Browne¹² have published general accounts of the igneous activity of New South Wales, while Richards¹³ has dealt with that of Queensland. One of the most remarkable differences in the accounts of the two States concerned the rhyolitic lavas of the Devonian period. Susasmilh points out that the Lower Devonian or "Volcanic series" of the Murrumbidgee area is made up entirely of rocks of volcanic origin, consisting of rhyolitic lava flows and tuffs which are the equivalents of the Snowy River Porphyries of Victoria. In the succeeding Murrumbidgean epoch, 8,000 feet of a total of 12,000 are composed of rhyolitic tuffs or tuffaceous sediments. "These two epochs," writes Susasmilh, "together constitute one of the great volcanic epochs of Australia."

It is interesting to contrast this statement with Richards's summary of Devonian activity in Queensland, where rhyolites are not even mentioned.

The recent discoveries announced above go far to remove this marked discrepancy between the records of igneous activity in Queensland and in New South Wales. Although the authors admit that there are no strong *a priori* reasons for assuming a close parallelism of igneous activity in the two States in Devonian times, there is a marked stratigraphical similarity with which the igneous record now seems to be in harmony.

The absence of volcanics of a rhyolitic facies from the extensive development of Devonian sediments in New England calls for some comment, in view of the great development of such rocks in the Murrumbidgee area to the south, and the great geographical range of those now recorded from Queensland. Two possible explanations present themselves, namely—(1) That for some reason unknown there was no volcanic activity of a rhyolitic nature in the New England area, and (2) that the equivalents of the Murrumbidgee Series are missing from the geological sequence of New England. The latter explanation reopens the old controversy with regard to the spatial and temporal relationships of these two developments of Devonian rocks in New South Wales, but it is not the intention of the authors to pursue that theme in this paper.

Whether all of the areas of rhyolitic activity in Queensland are to be regarded as exactly contemporaneous with the similar activity in

New South Wales, or whether they are even contemporaneous with each other, is a question that can be decided only when each of these areas has been studied in much more detail than has as yet been attempted

APPENDIX

9 Since the above paper was read, Miss D Hill, B Sc, has discovered a rhyolite (specimens of which she kindly collected for the authors) at Marblestone, some 20 miles south of Gladstone. The rhyolite is associated with bands of fossiliferous Devonian limestones, and strikes with them a few degrees west of north, the dip being approximately vertical. Miss Hill's discovery makes an important addition to our knowledge of the Devonian rhyolites of Queensland

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Contribution to the Queensland Flora, No. 4.

By C T WHITE, Government Botanist, and W D FRANCIS, Assistant Government Botanist

Plates IX and X

(Read before the Royal Society of Queensland, 26th August, 1929)

The last contribution (No 3) appeared in volume xxxvii of these Proceedings, pp 152-167. The present contribution contains descriptions and illustrations of two new species. A number of species are recorded for the State for the first time. A description of the flowers of *Findernia laevicarpa* White & Francis, is included, this species was described from fruit-bearing specimens only. Opportunity is also taken to give locality records of a few species whose range was previously little known.

ORDER RUTACEÆ

Findernia laevicarpa White and Francis. Described from fruit bearing specimens. Flowering specimens have been collected by Mr T Fuller of Gadgarrah, Atherton Tableland, and the following description of them is given.—Panicles terminal or in upper leaf axils, up to 10 in (25 cm) long. Calyx broadly cupular, about $\frac{1}{8}$ -in (2 mm) across, lobes 5, ovate, less than $\frac{1}{4}$ -in (1 mm) in length. Petals puberulent, ovate or narrowly ovate, nearly $\frac{1}{8}$ -in (2 mm) long. Stamens less than half the length of petals, anthers reniform, filaments and stamnodia (when present) very short and almost gland-like. Disk crenulate. Ovary globose, without conspicuous style or stigma.

ORDER RHAMNÆÆ

Sageretia hamosa Brongn. Freshwater Creek, below intake (Cairns water supply) near Cairns. W D Francis, 7-7-1928. Scandent shrub. Specimens were forwarded to the Director, Royal Botanic Gardens, Kew, for specific identification. In a letter the Director writes—"Mr V S Summerhayes has examined the specimen and reports that he cannot distinguish it from *S. hamosa* Brongn., a native of Southern India. *S. costata* Miq. from Java and Sumatra also seems to be identical with this species."

Pomaderris ligustrina Sieb. Brookfield, near Brisbane. Free flowering shrub about 3 ft high, only a few bushes seen. Mrs B F Cribb flowering specimens, 3-9-1928. This is the first record of the occurrence of this species in Queensland.

ORDER SAPINDACEÆ

Dodonaea hirsuta Maid & Bêche. Stanthorpe. J W Passmore. October, 1920. This record brings the known range of the species well within Queensland territory.

ORDER LEGUMINOSÆ.

Sesbania aculeata, Pers var *erubescens* Benth Leichhardt River, North-western Queensland Dr W MacGillivray (ex Herbarium A Morris Nos 2145, 2345) A definite Queensland locality for a little-known plant

Cyclostarpa stellaris Ait Kelsey Creek, near Proserpine, North Queensland, Rev N Michael (No 949) A new record for the State. Determination verified at Royal Botanic Gardens, Kew Previously recorded for Sierra Leone and the Cameroons, Tropical Africa

Cassia neurophylla W V Fitzgerald Journal and Proceedings Royal Society of Western Australia, vol 3, p 147, 1918 Specimens of this species were kindly forwarded by Mr W M Carne, late Botanist and Plant Pathologist of Western Australia, for comparison with *Cassia neurophylla* White & Francis, these Proceedings, vol XXXVII, p 156, 1926 The comparison leaves no doubt that the two names are applied to the same species. On account of priority in publication W V Fitzgerald's name takes precedence, and, in consequence, our name becomes a synonym

Labioclea Braham n sp Plate IX Frutex ramulis teretibus pubescentibus vel hirsutis, foliis 3-5 foliolatis, rhachide pubescenti, foliolis anguste ovatis vel ellipticis supra asperulis subtus pilis sericeis longis vestitis, margine recurvis, ad apicem valde mucronatus, utrinque reticulatis, racemis axillaribus rhachide pubescenti vel hirsuto, sepalis 4 lanceolatis vel anguste triangularibus acuminatis, sepalis supremis et sepalis infimis majoribus et extus hirsutis, petalis 4, glabris, staminibus 2, antheris linearibus, ovario dense tomentoso, breviter stipitato, stylo glabro, legumine elliptico ad apicem obliquo, pilis longis sparse vestito

A shrub Branches, leaf rachis, rachis of inflorescence and outer side of outer calyx segments pubescent or hirsute Branchlets terete Leaves pinnate Leaflets 3-5 The lower pair of leaflets are mostly inserted on the leaf rachis at or near its junction with the branchlet, sometimes there is a distinct common petiole up to 3 mm in length Leaflets asperulous above, clothed with long fine silky hairs beneath, ovate, elliptical or elongate-elliptical, margins recurved, prominently and rigidly mucronate at apex, prominently reticulate on both surfaces, lateral leaflets on petioles 1-2 mm. long, petiole of terminal leaflet 2-3 mm, blade of lateral leaflets 10-25 mm long, 2-3 times as long as broad, blade of terminal leaflet 25-40 mm long, 2½-3½ times as long as broad, the leaf dimensions include the 2-3 mm long spinulose point Racemes axillary, pubescent or hirsute, 15-3 cm long Pedicels 5-7 mm long Sep., 4, lanceolate or narrowly triangular, acuminate, 6-10 mm long, the uppermost and lowermost sepals are hirsute on the outside and are somewhat larger and firmer than the lateral ones which they enclose in the bud Petals 4, yellow, tinged or spotted with red, glabrous, 9-11 mm long Stamens 2; filaments 1 mm. or less in length, anthers linear, 4-7 mm. long Ovary densely tomentose, obliquely ovate, on a short stipes almost 1 mm long; style reddish, glabrous, about 3 mm. long. Ped elliptical, oblique at apex, finely hirsute especially on margins, on a stipes 1-2 mm long



Labichea Brassii (new species) Natural size

[Face page 140]

Photo Dept of Agriculture and Stock

Locality Forest Home Station, Gilbert River, North Queensland
L. Brass

Alied to *L. rupestris* Benth and separated from *L. rupestris* by its pinnate leaves. The species is named after its collector, Mr L. Brass. A specimen of the species was forwarded to Mr F. J. Rae, Government Botanist, Victoria, for comparison with material in the National Herbarium, Melbourne. In reply, Mr Rae stated that there is an exactly similar specimen in the Herbarium from Gilbert River, collector E. Daintree, labelled F v Mueller *Labichea nitida* var *pinnata*. In his *Fragments*, vol 10, p 7, 1876-1877, Mueller refers to this specimen from Daintree as a pinnate-leaved variety of *Labichea nitida*. Our specimens do not appear to represent a variety of *L. nitida* Benth as they have only 4 sepals and 4 petals and not 5 as in *L. nitida*.

Albisia xanthoxylon n. sp. Plate X. Arbor partibus junioribus ferrugineo-pubescentibus, folis bipinnatis, pinnis 1-jugis, foliolis 3-5 jugis, pinnulis petiolulatis ovatis vel lanceolatis, apice obtuse acuminatis, basi saepe obliquis, supra nitidis, venis et venulis utrinque prominulis, paniculis magnis et terminalibus, capitulis 20-30-floris, floribus sessilibus, calyce cylindrico 4- vel 5-dentato, dentibus minutis triangularibus, apice puberulis, corolla 4- vel 5-lobata, lobis ovatis, apice puberulis, tubo cylindrico, staminibus numerosis, antheris reniformibus minutis, ovario glabro fusiformi tenuiter stipitato, stylo tenui, legumine late lineari atrocastaneo, valvis extus reticulatis, seminibus transversis planis orbicularibus.

Wood and pith of branchlets yellow, young parts and rachis and branchlets of the inflorescence ferrugineous pubescent. Petioles 1-2.5 cm long. Leaves on flowering branchlets consisting of 1 pair of pinnae, each pinna with 3-5 pairs of leaflets. Petiolules 3-6 mm long, leaflet blades ovate or lanceolate, obtusely acuminate, midrib, lateral nerves, and reticulate veins visible on both surfaces, upper surface glossy, 3-5 lateral nerves on each side of midrib, 3.5-9 cm long, 2-2½ times as long as broad. Panicle large and terminal, the ultimate branches bearing fascicles of 20-30 sessile flowers. Flowers glabrous except puberulent apices of calyx lobes and corolla lobes. Calyx cylindrical, 2-3 mm long, 1 mm diam, teeth 5 or 4, minute, subtriangular. Corolla 6 mm long, lobes 5 or 4, ovate, 2 mm long, tube cylindrical. Stamens numerous, 9-10 mm long, tube cylindrical 4 mm long, free from corolla tube, anthers reniform, minute. Ovary glabrous, fusiform, on a slender stipe 2 mm long, style slender, 7 mm long. Pods strap-shaped, 7-12 cm long, 17-20 mm wide, surface reticulate. Seeds orbicular, flat, 10-15 mm diam.

Locality Atherton District, North Queensland, Overseer Crothers of Provisional Forestry Board, end of October, 1927.

Among Australian species of the genus the new species resembles *Albisia procera* in some ways, but is distinguished from *A. procera* by the leaflets tapering towards the apex.

ORDER RHIZOPHOREÆ

Bruguiera sexangula Poir (*B. eriopetala* W & A) North Queensland coast without specific locality G Tandy XII, 1928 A new record for the State The species is distributed in Southern India, Malay Peninsula and Islands, and China

ORDER MYRTACEÆ

Agonis lymnophala F v M Shrub 4-8 ft Yarrabah, North Queensland, Rev N Michael (No 1648) This is a new locality record for a little known plant The Rev Michael's note on the species may be of interest — "On a large dead stump on the side of the road I saw a big bundle of it tied together and drying in the sun Hence the dead appearance of the specimen I remember often having seen bundles lying about drying The natives shake off the dead leaves and fruits and use the bundles as rough brooms to sweep round their huts They told me it is only gathered at a certain swampy region "

Eucalyptus odontocarpa F v M Between Headingly and Barkly Downs Stations, near the Northern Territory Border, Queensland Dr W MacGillivray (No 2172) (Received from A Morris) Dr MacGillivray writes — "Specimens of this tree were collected after crossing the Templeton River, between Headingly and Barkly Downs Stations, in lightly timbered porcupine country where there were numerous termitaria It is a mallee-like gum, several stems growing from a common base " The species was previously known from the Northern Territory and the Kimberley District of North-Western Australia

Eucalyptus quadrangulata Deane & Maiden Parish of Gladfield about 32 miles from Warwick, Darling Downs, Forest Factor W J Gorman Determined by Mr W F Blakely of the Botanic Gardens, Sydney Mr Gorman writes — "A tree, in appearance like gum topped box, having all the appearances of that species both in field characteristics and appearance of the wood Some of the trees out 80 ft of timber clear to the first limbs The only place I have noted this particular species occurring is on the State Forest Reserve 405, Parish of Gladfield, situated on the western summit of the Great Dividing Range, about 32 miles from Warwick and about 12 miles from Maryvale railway station It occurs in scattered clumps on the spurs separating the waters of the Goomburra Valley and Maryvale Valleys, and about 1 mile to 1½ miles from the summit of the Great Dividing Range It occurs chiefly on open forest areas on the very summit of spurs In one instance only a clump of trees was noticed on the edge of a dense vine scrub half way down one of these spurs " Previously only known from New South Wales

ORDER CAMPANULACEÆ

Isotoma longiflora Presl Naturalised about Innisfail, North Queensland H G Ladbrook, C T White A native of the West Indies, naturalised in Java A new record for the State



Albizia xanthophylla (new species). Inflorescence bearing bractelets on right. Leaf on left p_{10} , leaflet 4 on right and 5 on left.

ORDER EPACRIDÆ

Leucopogon nubsous R Br Wallangarra, New South Wales-Queensland border, J L Boorman, vii, 1904 Inglewood, C T White Plunkett, about 30 miles south-west of Brisbane, C T White (No 5591), 24-2-29 A new record for Queensland The Wallangarra specimens are from the National Herbarium, Botanic Gardens, Sydney, and bear the following note — "The collector is doubtful whether the specimens were collected in Queensland or New South Wales They are very imperfect, but we have no better specimens from this locality" The Plunkett specimens match the Wallangarra ones perfectly, both differ from the type, which grows from Port Jackson to the Blue Mountains, in the leaves being acute, not "obtuse or with a minute callous point" as described in the "Flora Australiensis", the floral parts however seem to agree very well

ORDER MYOPORACEÆ

Myoporum platycarpum R Br Reserve 79, Whetstone, near Inglewood, approaching border of New South Wales R H Doggrell As the specimens bear leaves only, flowering or fruiting material is required for confirmation Not previously recorded for Queensland

ORDER ILLECEBRACEÆ.

Paronychia brasiliensis DC Toowoomba, F B Coleman, 3-12-1927 A native of Southern Brazil We are indebted to the Director, Royal Botanic Gardens, Kew, England, for the specific determination

ORDER CHENOPODIACEÆ

Roussaea multifida Moq A native of South America but now widely distributed over the warm temperate and sub-tropical regions of the world A new record for the State The Clerk, Rosenthal Shire Council, Warwick, wrote, under date 13-1-1928 — "I send you a specimen of a plant brought in by a Councillor from Leyburn It is a strong grower and the leaders spread along the ground"

ORDER LORANTHACEÆ.

Loranthus Gandichandii DC Inglewood (approaching border of New South Wales), parasitic on *Melaleuca decora* Salisb C T White (No 6143), 28-11-1922 Shrub with blood-red flowers Not previously recorded for Queensland

ORDER EUPHORBIACEÆ

Poranthera corymbosa Brongn Messines, via Cottonvale, Stanthorpe District M Greener Not previously recorded for Queensland

Changes in Osmotic Pressure in Relation to Movement of *Mimosa Pudica*.

By D A HERBERT, D Sc (Department of Biology, University of Queensland)

(Read before the Royal Society of Queensland, 26th August, 1939)

In a former paper¹ on the effect of various reagents, including anæsthetics, on the movement of *Mimosa pudica*, evidence was presented in support of the theory that anæsthesia, in so far that it implies a suspension of sensitivity, is a term which cannot properly be applied to the effect of ether and chloroform on the sensitive plant. The evidence may be summarised as follows—When the living plant is subjected to the action of chloroform or ether no suspension of activity occurs unless the plant is permanently injured. Gaseous poisons such as sulphur dioxide, ammonia, formalin, and hydrogen sulphide have the same effect on movement of the living plant, when introduced under a bell jar, as have ether and chloroform. In low concentrations response is normal, and activity is suspended only when permanent injury has been inflicted. Temporary suspension of activity can only be induced by placing the plant under conditions unfavourable to its normal metabolism. Absence of light or of oxygen may do this. The stimulation which has been reported from the effects of low concentrations of ether and chloroform by such workers as Thoday², Irving³, Haas⁴, and others has not upset the co-ordination of metabolic processes, irregularities are produced when the action becomes irreversible, or, in other words, when permanent injury has been produced. When portions of the stem with the leaf attached are immersed in ether solution the rate of bending is proportional to the concentration of the solution, and until the petiole is fully depressed the pulvinus retains the power of movement, when stimulated by heat, through the remainder of the arc. The pulvinus behaves in the same way towards lipid solvents. Enzyme poisons react differently, and movement is not directly connected with enzyme destruction, though naturally affected by it as by any other effect on the plant's health. It was concluded that the effects of ether and chloroform on the movement of *Mimosa pudica* were the result of the lipid solvent properties of these substances.

The action of alcohol, which is a mild animal anæsthetic, is complicated by the fact that it prevents movement after a time by coagulating protoplasm. The present paper is largely an attempt to elucidate the behaviour of the pulvinus of *Mimosa pudica* towards this reagent.

The work of W H Brown¹ in 1912 drew attention to the fact that pulvini, which had remained erect after having been killed by heat, curved when subsequently passed through various grades of alcohol and finally to xylol. This was interpreted as being the result of the artificial change of osmotic pressure induced by the treatment. The suggestion has been made that this movement is closely connected with dehydration phenomena. In my former paper the re-erection of petioles dehydrated by alcohol was contrasted with the permanent bending of those treated with ether (p 138). The re-erection of petioles relaxed by dehydration with alcohol was regarded as a point, though not the main one, in support of the idea of the lipid solvent action of ether and chloroform as the important factor in their effect on movement. It is necessary therefore to determine whether the depression and re-erection observed during the treatment with alcohol and subsequently with water are due to an osmotic effect or not. In this paper it is proposed to deal also with the effects of coagulation on movement of the pulvinus.

Material was obtained from strongly growing plants raised in the open in Brisbane, and consisted of short pieces of stem, each with a petiole attached, the pinna having been removed in each case. As a large number of plants had been raised for the purpose each experiment was repeated at least twenty times, and the material used was as uniform as possible with regard to health and age. Young and old leaves were discarded. It was not possible to use throughout the work leaves whose petioles made the same angle with the stem, as this angle varies greatly according to the position of the leaf on the stem, the angle of the stem (which is straggling), and the surroundings.

It was pointed out in the last paper that this stem petiole material when allowed to erect in water or in a moist atmosphere shows a sudden and characteristic movement at or about 67 deg C, the temperature varying slightly with different specimens. The petiole suddenly becomes depressed, and after describing the full arc suddenly returns through an arc of 5 deg or 10 deg. After this no more movement is possible. The power of re-erection is permanently lost. The double movement is interpreted as a heat response followed by a coagulation of the protoplasm of so many of the cells that a return movement is produced. The movement cannot be the result of shock caused by difference of temperature, as in the experiment this was raised slowly enough to preclude such a possibility. The coagulation of some of the cells at this point is apparently the cause of internal movements which are a sufficient stimulus to cause a response before coagulation has proceeded to such a degree as to prevent it, and the subsequent return then follows. A microscopical examination before and after heating in water to the reaction point shows that coagulation of a large number of the cells does actually take place at this temperature. The protoplast in such cells is dark, shrunken, and granular.

As the contraction of the cells of the lower half of the pulvinus is responsible for the first bending, any further contraction due to coagulation should produce more contraction in the convex half than in the

already contracted concave half, thus producing a return movement. If this theory is correct the removal of one half of the pulvinus and subsequent heat treatment should result in a single movement with no return. A number of pulvini were therefore treated by the excision of the upper half, others having the lower half removed. The former responded, as was to be expected, by bending downwards, the latter by bending upwards. On immersion in water a recovery took place, those specimens with the upper half of the pulvinus removed erecting their petioles through a considerably greater angle than was possible with the intact material. In some cases the upward bending was so pronounced that the petiole was reflexed to an angle of -30° with the stem. Recovery of material in which the lower half of the pulvinus had been removed involved a depression of the petiole. (This behaviour is well known and has been described in various papers by Bose, the responses of the upper half and the lower half to electrical stimulus have been investigated by Bose and Das⁶, who find that the response to stimulus of the upper half, which is antagonistic to that of the lower half, is very sluggish.) Preparations were gradually heated in water and it was found that although the petioles had in water at 25°C reached a certain angle and remained stationary there, they moved slowly to a somewhat greater amplitude as the temperature was gradually raised. This should be expected as the result of heating. The amplitude increased until at the temperature of 67° there was a sudden return upwards where the under half of the pulvinus had been removed, and downwards where the upper half had been removed.

As in the case with all these experiments, the actual angles before and after treatment varied considerably according to the position of the leaf on the branch, the angle of the branch on the plant, and to the direction of lighting of the plant. The following examples are typical when allowance for these factors has been made —

Experiment 1—

- Original angle of petiole with stem of the plant, 100°
- Angle after removal of upper half of pulvinus, and recovery in water at 25°C , 0°
- Angle after slow raising of the temperature to 65° , -15° (reflexed)
- Angle after the bending at 67° , 45°
- There was no return movement

Experiment 2—

- Original angle of petiole with stem of the plant, 100°
- Angle after removal of lower half of the pulvinus and recovery in water at 25°C , 130°
- Angle after the bending at 67°C , 80°
- There was no further return movement

It was impossible to test the effect of heat on relaxed pulvini immediately after the excision of one half of the pulvinus in order to study the simple contraction due to coagulation. When such pulvini are placed in water their recovery is extremely rapid. The following gives an indication of the speed of the movement—

Experiment 3—Rate of recovery in water at 25 deg C of pulvini with the lower half removed—

Angle of petiole with intact pulvinus after stimulation, 130 deg

Angle of same petiole after removal of lower half of pulvinus, 110 deg

Angle after immersion in water, 30 deg

Time, 20 seconds

Experiment 4—Rate of recovery in water at 25 deg C of pulvini with the upper half removed—

Angle of petiole with intact pulvinus after stimulation, 45 deg

Angle of petiole with upper half of pulvinus removed, 50 deg

Angle after immersion in water, 45 deg

Time, 20 seconds

These rates may be compared with the normal rate of recovery of an intact specimen when placed in water. This, at a temperature of 25 deg, is usually about 21 minutes. The effect of most reagents tried was greatly accelerated by removal of part of the pulvinus. For example, it was found that coagulation by alcohol was effected in quarter the time if part of the pulvinus was removed. The behaviour in water of dissected material opens up an interesting phase of the subject of response. The 20-second response indicates that the reappearance of osmotic substances in the cell is very rapid indeed after the excitatory response. A pulvinus in which thin slices have been removed from the sides but not from the top or the bottom shows the same rapid response, about 20 seconds being the time involved instead of the normal 21 minutes. The significance of this will be discussed at the end of the paper.

Experiments 1 and 2 show that the double movement of the intact erect pulvinus heated to about 67 deg C is actually due to the differential response of the upper and lower halves. When one half is removed and the remainder given the heat treatment, only a single movement is produced. In the intact pulvinus the response at 67 deg followed by the slight return movement may be interpreted, therefore, as the normal shock response caused by commencement of coagulation in the tissues, followed by more or less complete coagulation which produces the return movement, the opposition of the lower and upper halves being responsible for its relatively small amplitude.

Effects of Alcohol—The effects of alcohol on the pulvini were studied, making use of the movement which has been described above

Since the ultimate effect of alcohol on the protoplast is coagulation, as pointed out by Seifriz' in the case of *Elodea*, it was first necessary to determine the time taken for this to take place to a sufficient extent to interfere with the experimental procedure

Experiment 5 — Coagulation in intact pulvini by alcohol —

A large number of pieces of stem-petiole preparations were placed in absolute alcohol and at intervals of 10 minutes a few withdrawn and placed in water for 10 minutes. They were then gradually heated to 67 deg. It was found that 20 minutes in absolute alcohol did not prevent their re-erection after dehydration but that after 30 minutes some effect could be noticed, and after 110 minutes coagulation prevented any movement except in a few cases. After this time there was no re-erection on immersion in water or change on heating to 67 deg. Below that there was re-erection, and at 67 deg a return movement, the amount depended on the length of time that the material had been in the alcohol.

Microscopic examination confirmed the assumption that coagulation had occurred, and the similarity of angle of pulvini after heat treatment and after alcohol treatment may be regarded as supporting evidence.

Experiment 6 — Coagulation by alcohol in pulvini with one half removed —

A similar experiment was carried out with two sets of material, in one the lower half, and in the other the upper half of the pulvinus being removed. After seven minutes coagulation prevented any further movement in most of the pulvini, either in response to immersion in water or to heat treatment after immersion in water, though a few still reacted slightly. The average angle of pulvini with the upper surface removed was, after seven minutes in absolute alcohol, about 30 deg, and of those with the lower surface removed, about 130 deg.

Here we have another example of the shortening of the reaction time by the removal of part of the pulvinus.

The effects of alcohol in coagulating the protoplast having been ascertained, experiments on its effects as a dehydrating agent could be undertaken with precautions to guard against this source of error. It is evident that pulvini from which one half has been excised could not be used in experiments involving dehydration because of the rapidity of coagulation.

First, the effects on erect and on relaxed material were determined.

Experiment 7 — Portions of stem-petiole material were placed in absolute alcohol immediately after their amputation. Their angles were measured before and after dehydration. A typical case was as follows —

Angle of depressed petiole, 80 deg

Angle after dehydration, 80 deg

Angle after transfer to water for one hour, 80 deg

These results may be contrasted with the following:—

Experiment 8—Portions of the erect material were placed in alcohol—

Angle of erect petiole, 70 deg

Angle after dehydration, 95 deg

Angle after transfer to water for one hour, 70 deg

These experiments being carried out under similar conditions and large numbers of specimens being employed, the possibility of the difference in behaviour being due to coagulation in the case of Experiment 7 is out of the question. The different behaviour is readily explained by the fact that one experiment started with pulvini whose cells possessed their full osmotic pressure, while the other started with those whose turgor had been lost. If the re-erection of the dehydrated material on treatment with water were due to osmotic absorption there would be the expected results. If this re-erection were due to the dehydration of the tissues, other than by osmosis, even in part, some re-erection should have been observed in Experiment 7. Such was not the case, and it must be concluded that this artificially produced movement is essentially an osmotic one.

Effect of Ether—Further experiments on material treated as in the last experiment (Experiment 8) were carried out to lend further support to this idea.

Experiment 9—Erected material was dehydrated in absolute alcohol and the petioles became depressed. They were then removed to a 5 per cent solution of ether. No re-erection took place.

Experiment 10—A modification of the last experiment was tried. Erected material was placed in a mixture of equal parts of alcohol and ether. A fall of the petiole took place, and on transference to water at the completion of the depression no re-erection took place. Similar results are produced by substituting benzene or chloroform for ether.

In these cases the only difference in experimental procedure was the treatment of the material with ether (or in confirmatory experiments with benzene or chloroform). The difference in results was the failure to re-erect. Here then is further support for the theory of the osmotic behaviour of dehydrated pulvini.

Erected material was placed in a 5 per cent solution of ether. In one series of experiments the upper half of the pulvinus, and in the other the lower half, was removed.

Experiment 11—Erect pulvini placed in 5 per cent ether solution, upper half of pulvinus removed. In a typical example the pulvinus was sharply turned back, the petiole making an angle of -60 deg with the stem. After one hour in the ether solution (to ensure the maximum effect) the angle was -5 deg, showing a movement of 55 deg. On transference to water no re-erection took place. On warming there was no action until at about 67 deg, the petiole subsided slowly to 20 deg, a fall of 25 deg. This behaviour was characteristic, though of course amplitudes varied with different specimens.

Experiment 12—Erect pulvini with the lower half of the pulvinus removed were placed in a 5 per cent solution of ether. The following was the behaviour of a typical sample.—The angle of the turgid material with the stem was 135 deg. The petiole was depressed. After ether treatment for one hour it had risen to 90 deg., and on transference to water showed no further movement. It was then heated in water, and rose to an angle of 75 deg $\rightarrow e$, the petiole rose through 15 deg. Other specimens behaved similarly except for amplitude.

Pulvini were now given similar treatment when in the fully contracted condition.

Experiment 13—Material with the upper half of the pulvinus removed was immersed in 5 per cent ether solution for one hour in the fully contracted condition. The following are the measurements of a typical specimen—

Angle before ether treatment, 60 deg

Angle after one hour in ether solution, 60 deg

Angle after hot water treatment, 50 deg

There was an erection of 10 deg in this particular case

Experiment 14—Material with the lower half of the pulvinus removed while in the fully contracted condition was immersed in 5 per cent ether for one hour. The following are the measurements of a typical specimen—

Angle before ether treatment, 100 deg

Angle after one hour in ether solution, 100 deg

Angle after hot water treatment, 85 deg

There was an erection of 15 deg

From these four experiments (11, 12, 13, and 14) it is seen that the original turgidity of the material has no effect on the final result when the tissue is treated with ether. This is as would be expected if ether destroys the osmotic character of the protoplast. The erect pulvini after treatment by this method lose their turgidity, and, this effected, their subsequent behaviour on the application of heat is the same as that of the originally contracted pulvini. The effect of ether does not interfere with the coagulation movement which naturally is upwards in specimens in which the lower half of the pulvinus has been removed, and downwards where the upper half has been excised.

DISCUSSION

The work of Blackman and Paine^a indicates that the loss of turgor in the cells of the pulvinus of *Mimosa pudica* cannot be explained by a sudden increase of the permeability of tissues allowing the rapid exosmosis of dissolved substances. The conductivity method used by these investigators showed that loss of turgor was due to the inactivation of a considerable part of the osmotic substances of the cells. Brown's work (*loc cit*), which had been published some six years before, had

been an attempt at the artificial lowering of osmotic pressure in the cells by dehydration, and was successful inasmuch as a contraction of the pulvinus was produced. The experiments described in this paper confirm Brown's conclusions, and show that the movement during dehydration and subsequent re-erection when the pulvini are transferred to water is actually dependent on the change of osmotic conditions. When erected material is dehydrated a curvature takes place, and re-erection is possible when the material is replaced in water. When material in which the pulvini are in the relaxed state is dehydrated and then transferred to water, no re-erection takes place, if the bending were a simple dehydration phenomenon independent of osmotic changes, or partly so, a re-erection at least in some degree should be observed. The alteration of the permeability of the protoplasmic membrane by treatment with lipid solvents prevents a re-erection of material which, originally in the erect condition, has been dehydrated in alcohol. From these two points of attack, therefore, support has been given to the view that the movement induced by dehydration is an osmotic phenomenon. Sen³ concludes from his work on the electrical resistance of living tissue that the loss of turgor in stimulated plant tissue is brought about by the induced permeability of the cell membrane. He points out that, as Blackman and Paine admit, non-electrolytes form a considerable portion of the osmotically active substances within the cell, and that the amplitude of response of the leaf of *Mimosa* closely corresponds with the diminution of resistance of the pulvinus. In view of the small amount of the exosmosed electrolytes, however, it seems unwarranted to assume, without definite proof, a sufficient exosmosis of non-electrolytes to cause the movement.

As has been shown in this paper, the sudden fall of a leaf on stimulation is followed by an immediate very rapid recovery if part of the pulvinus is removed. Re-erection is about sixty times as rapid in such a specimen as that in intact material if water is available. If it is not available, recovery does not take place, but a cut pulvinus still relaxed after some time in air, becomes turgid again in twenty seconds when replaced in water. The relatively slow recovery in water when intact material is used is not due to the opposition of the movements of the two halves. If portions of the tissue on either side of the pulvinus are removed and the stimulated material placed in water, re-erection takes place in twenty seconds, as it does when top or bottom halves are removed. This rapid recovery explains why Hilburg's plasmolytic investigations revealed no decrease in osmotic pressure in stimulated pulvini. The slow return of the intact pulvinus to the turgid condition, and the rapid return of a pulvinus in which some of the surface tissue has been removed, indicates that the difference is due to the amount of water available. The recovery of potential osmotic pressure in stimulated pulvinar cells is therefore extremely rapid and is not to be gauged by the rate of movement of recovery in the uncut organ. Such behaviour makes it still more difficult to accept the theory of a sudden increase of permeability in the protoplasmic membrane on stimulation. These

experiments show that if such were the case it must be followed almost immediately by a sudden decrease, and the reabsorption of escaped substances at such a rate is unlikely. Further, in the sliced material escape into the water in which it is immersed would be rapid, and would not permit of the repeated response observed when such material is subjected to shock time after time.

The effect of alcohol on the movements of the pulvini also lends support to the contention that the contraction is due to the inactivation of osmotic substances rather than a sudden increase in permeability of the protoplasmic membrane.

The failure of re-erection on the part of dehydrated pulvini, which, before the alcohol treatment were erect, when they are treated with ether is explained as due to the lipid solvent action of this reagent which has been discussed in the previous paper (*loc cit*)*. Whether pulvini are contracted or erect, the final angle is the same after ether treatment, which indicates that their osmotic conditions are the same.

The establishment of these points in conjunction with the evidence formerly presented is advanced as support for the statement that the action of ether and chloroform (which behaves similarly in this respect) on the movement of *Mimosa pudica* is essentially the action of lipid solvents.

SUMMARY

1 When pulvini of *Mimosa pudica* are heated in water, a sudden contraction, followed by a slight return movement through about 10 deg., takes place when the temperature reaches approximately 67 deg. C. Evidence is presented that the return movement is due to coagulation which takes place in both halves of the pulvinus but which, because the lower half is already contracted, is more noticeable in the upper half.

2 When a contracted pulvinus from which part has been excised is placed in water, recovery takes place in 20 seconds, the uncut pulvinus requires about 21 minutes under similar conditions. From this it is deduced that the recovery of potential osmotic pressure is much more rapid than would be expected from a consideration of the rate of recovery of an uncut pulvinus.

3 Pulvini treated with absolute alcohol show the commencement of coagulation after 30 minutes, and after 110 minutes only an occasional specimen showed any response. Pulvini from which portion had been excised were usually prevented from showing any movement after seven minutes.

4 The action of alcohol on the pulvini is to cause a contraction which is due to reduction in osmotic pressure. The dehydration of pulvini which are already contracted, if followed by transfer to water, does not result in any erection as would be the case if movement were

* A full statement of the case in support of the view of the regulatory action of lipoids on the passage of material into and out of cells has recently been presented by MacDougall**

due to simple swelling, whereas similar treatment of originally turgid pulvini results in re-erection

5 The treatment of such material with ether prevents any such re-erection This is interpreted as evidence in support of the lipid solvent action of ether on the protoplasmic membrane, similar results being produced by the use of chloroform or benzene

6. The treatment of living pulvini with ether solution produces a final angle which is the same whether the pulvini were originally turgid or contracted

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Chemical Constituents of the Bark of *Melicope erythrocarpa*.

By T G H JONES, D Sc, and M WHITE, M Sc

(Tabled before the Royal Society of Queensland, 28th October, 1939)

Melicope erythrocarpa is a medium-sized tree native of Northern New South Wales and South-Eastern Queensland. In the latter State it is most abundant in the drier type of scrub or rain forest, such as occurs in the neighbourhood of Toowoomba, Nanango, Yarraman, Kilkivan, Burnett River, &c

The bark of the tree is rough, thick, and of greyish colour, and is possessed of a characteristic and somewhat penetrating odour. Our attention was drawn to the necessity of an investigation of this bark by the Forestry Department, Brisbane, on account of reports received of irritating effects produced on the eyes of axemen cutting the trees and of the peculiar tingling sensation produced by the bark on the tongue, accompanied by stimulation of the salivary flow. It may be noted that this latter feature had formerly been commented on by Mr H Tryon, who considered it worthy of the attention of the medical faculty.

Examination of bark supplied from Yarraman, by Forestry officials, has resulted in the isolation of elimicin as principal constituent (90 per cent) of the essential oil contained in the bark, to the extent of about 8 per cent in young trees, with lesser amounts in older trees.

The effects noted above seem to be due to the presence of this constituent, as it is much more pronounced with the free substance than with the original bark and is also possessed by elimicin obtained from another source. No other constituent of the essential oil could be isolated and characterised.

The bark also contains as an important constituent a crystalline substance which is identical with lupeol, an alcoholic body isolated by other investigators from the peelings of lupin seeds,¹ the bark of *Soucheira griffithiana*,² gutta percha,³ and apparently of wide distribution. Although conflicting statements regarding its composition and derivatives appear in the literature, the later investigations of Cohen⁴ have resulted in more accurate knowledge. This author concludes that lupeol is a mixture of two substances of molecular composition $C_{30}H_{50}O$. Our results confirm most of the data obtained by Cohen, except the

molecular composition, which we believe is more accurately represented by the formula $C_{30}H_{48}O$, isomeric with the amyriins¹, the specific colour reactions of which are also given by lupeol

EXPERIMENTAL.

In our examination of the bark, attempts to remove the essential oil by steam distillation resulted only in imperfect separation, and we have made use of percolation methods, using ether as a solvent on the small scale and light petroleum with larger amounts of bark

Ten pounds of finely-ground bark on extraction with ether gave, after removal of ether and distillation of the residue *in vacuo* with glycerine, 38 ccs [8 per cent] of oil with the following constants —

d_{15}	1.0343
n_D^{20}	1.501
$[\alpha]_D$	1.4
Acid value	nil
Acetyl value	nil
Ester value	29

Fractionation of 35 ccs of the oil at 30 mm pressure resulted in the isolation of 30 ccs of a fraction b.p. $180^\circ C$ with a small lower fraction 2 ccs

For the large fraction (30 ccs) the following constants were obtained —

d_{15}	1.068
n_D^{20}	1.5280

These constants suggested elimicin, which was confirmed by the following experiments —

(a) Combustion results—

Found C 69.5 per cent H 7.7 per cent
 $C_{30}H_{48}O_2$ (elimicin) requires C, 69.2 H 7.7,

(b) Methoxy determination—

2574 grs gave 7748 grammes AgI, indicating three methoxyl groups

(c) Oxidation with potassium permanganate in alkaline solution gave trimethyl gallic acid M.P. $169^\circ C$

(d) Conversion to iso-elimicin by boiling with sodium ethoxide solution, from which was prepared iso-elimicin dibromide M.P. $88^\circ C$

Isolation of Lupeol—As the residue left after removal of the elimicin from the ether extract, in the experiment recorded above, gave indications of the presence of a crystalline substance, larger quantities of bark (60 lb) were crushed and repeatedly extracted by percolation

with low-boiling petroleum ether. The greater portion of the solvent was removed by distillation, resulting in the deposition of considerable quantities of semi-solid material, which was separated as far as possible from the oily liquor containing the essential oil [70 ccs. eliminon were obtained from this oil].

The semi-solid material—from which on the small scale crystals of lupeol could eventually be obtained by draining on a porous tile and recrystallisation of the resulting solid*—was boiled under reflux with alcoholic sodium hydroxide to hydrolyse fats and esters and the lupeol extracted with petroleum ether.

After this treatment the lupeol could be readily crystallised from alcohol and, after purification, needle-shaped crystals were obtained M.P. 212°C . Yield of purified lupeol 52 grammes.

Combustion results—

Found C = 84.3 H 11.6

$\text{C}_{30}\text{H}_{50}\text{O}$ requires C 84.5 H 11.7

Lupeol acetate, prepared by acetylation, melted at 214°C . The acetyl value was 120.

Lupeol regenerated from the acetate melted at 212°C .

Lupeol benzoate prepared by benzylation, melted at 264°C .

Lupeol phenyl carbimide, prepared by the action of phenyl isocyanate, melted at 226°C .

Lupeol Bromo Acetates—Two mono-bromo acetates were obtained by adding bromine in carbon tetrachloride to lupeol acetate in the same solvent.

Separation was effected by fractional crystallisation from alcohol.

The more sparingly soluble bromo-acetate separated in crystalline plates, and melted at 204°C , and contained 14.7 per cent. of bromine.

The second bromo-acetate (crystalline needles), more soluble in alcohol, and therefore not as readily purified, contained 16.6 per cent. of bromine, and melted at $166\text{--}168^{\circ}\text{C}$. Recovery of the acetates from their bromo derivatives by reduction with zinc dust and glacial acetic acid gave two acetates of M.P. 214°C and 156°C respectively. From the former of these—that is, from the least soluble bromo-acetate, and obtainable in sufficient amount, the lupeol was recovered by hydrolysis. The melting point was 211°C , and on analysis gave results in agreement with the formula $\text{C}_{30}\text{H}_{50}\text{O}$.

We were unable to obtain sufficient pure alcohol from the second bromo-acetate for analysis, but the percentage of bromine would indicate a different molecular composition from $\text{C}_{30}\text{H}_{50}\text{O}$.

Lupeol bromo-benzoate—This was prepared in similar manner to the bromo-acetate, and the sparingly soluble bromo-benzoate [Br = 12.7

* Crystals so obtained possessed specific rotation $[\alpha]_{\text{D}} = +31.4$. The bulk of our material, obtained after hydrolysis of fats, was inactive, and therefore racemised during the hydrolysis.

per cent], recrystallised from acetone and then from ethyl-acetate, melted at 240°C . Our supplies of material were inadequate for definite isolation of the second bromo-benzoate analogous to the second bromo-acetate.

These results are in substantial agreement with those of Cohen, and confirm his view that lupeol is a mixture of two substances, one, however, apparently present to a much greater extent than the other.

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 - 5 Jungfleisch and Leroux also expressed this view
-

***Cyttaria septentrionalis*, a New Fungus attacking *Nothofagus Moorei* in Queensland and New South Wales.**

By D. A. HERBERT, D.Sc.,

(Department of Biology, University of Queensland)

Plate XI

(Read before the Royal Society of Queensland, 25th November, 1929)

The genus *Cyttaria* comprises five recognised species parasitic on the Beeches (*Nothofagus* spp.) of South America, New Zealand, and Australia.¹ *C. Gunnu* Berk occurs in Tasmania on *Nothofagus Cunninghamii*, but not on *N. Gunnu*. McAlpine² records it from Victoria from the former species. It is reported by Simpson and Thompson³ as the greatest opponent of the forest growth of *Nothofagus Menziesii* in New Zealand. *C. Purdiei* Buchanan, described from *N. fusca* in New Zealand, is regarded as belonging to *C. Gunnu*. Buchanan's description is very brief and inadequate, but his illustration shows that this species was almost certainly the one described by Berkeley from Tasmania thirty-seven years before. *C. Besteri* Berk attacks *N. obliqua* in Tierra del Fuego, Patagonia, and Chile; *C. Darwini* Berk attacks *N. antarctica* and *N. betuloides* in Tierra del Fuego, Patagonia, and Chile; *C. Harioti* Fischer is found on *N. betuloides* and *N. antarctica* in Tierra del Fuego; and *C. Hookeri* Berk occurs on the branches of *N. obliqua* and *N. antarctica* in Tierra del Fuego, Patagonia, and Hermit Island, Capo Horn. *C. disciformis* Lev., a tremelloid fungus found in dead bark in Chile, is not regarded as a *Cyttaria*.

Of the twenty-one species of *Nothofagus* recognised (under *Fagus*) in the Index Kewensis, eleven are South American, seven New Zealand, and three Australian species. There are in addition a number of hybrids described from New Zealand.

Cyttaria is confined to the genus *Nothofagus*, but as the records show, more than one species of beech may be attacked by the same species of fungus, while the same beech may be parasitised by more than one species of *Cyttaria*. The wide range of *Cyttaria* and its occurrence on different host species raised the question as to its possible occurrence in New South Wales or in Queensland on the northernmost of the southern beeches—*Nothofagus Moorei*. This species occurs in Queensland on the higher levels of the McPherson Range at an altitude of approximately 3,000 feet from sea level, and also in various localities in New South Wales as far south as the Gloucester River.

An unsuccessful search was made in May, 1928, for *Cyttaria* in the beech forest of Roberts Plateau, but the O'Reilly brothers, residents of the Plateau, from a description of the Tasmanian species, said that they had at times seen such a fungus near the New South Wales border. In May, 1929, on another visit to the area, a number of the typical galls, similar to those found on *N. Cunninghamii* when it is attacked by *Cyttaria Gunnii*, were collected, and the O'Reilly brothers reported that two of the fruiting bodies had been brought back from the border in November by a visitor, but had unfortunately been lost. There seemed little doubt, therefore, that *Cyttaria* was to be found in Queensland on *N. Moorei*. Mr C. T. White, F.L.S., Government Botanist, at the beginning of September, 1929, while visiting Mount Hobwee, about 14 miles south of Beechmont and on the New South Wales border, obtained young stromata of a typical *Cyttaria*. These were already the size of *C. Gunnii* but were far from mature, the cover layer of the apothecia being intact and the asci undeveloped. On 17th September, therefore, the same locality was visited by the writer, and by that time it was possible to obtain a satisfactory amount of mature material.

Mount Hobwee is on the border of Queensland and New South Wales, at the eastern end of the Queensland National Park. It reaches an altitude of 3,580 feet. The *Cyttaria* was collected both sides of the border. Only a few acres of beeches were attacked on Mount Hobwee, and those near the summit. The moss-hung branches and the general character of this patch seemed to indicate that the cloud-belt was the important factor in the localisation of the fungus. Similar conditions obtain at Mount Wanungra, a few miles west, where the other evidence of the presence of *Cyttaria* was found.

The name of *Cyttaria septentrionalis* is proposed for the new species, on account of its being the northernmost member of the genus. The description is as follows.—

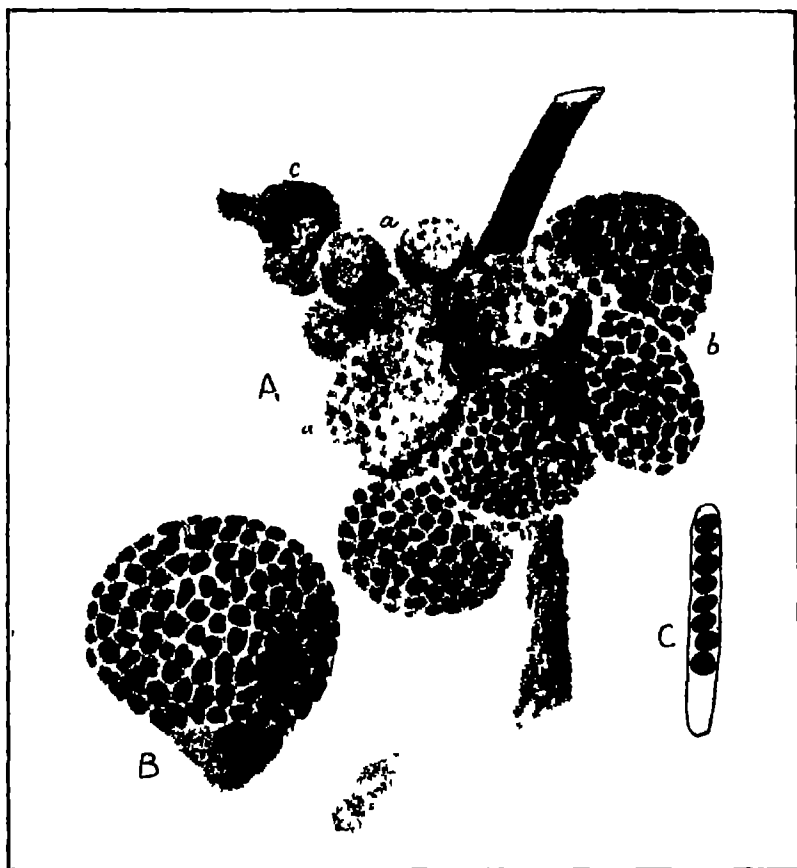
Cyttaria septentrionalis sp. nov.—stromata gregaria, globosa, 5-7 cm diam, demum cava, superficie ubique locellata, flava, locellis 3 mm latis, ascis cylindricis 170-210 μ longis, 17 μ latis, octosporis, non stipitatis, sporidiis globosis, 15 μ diam., paraphymbus filiformibus, species edulis. Hab. in summo monte Hobwee, ad ramos vivos *Nothofagi Moorei*, Sep. 1929.

The new species is distinguished immediately from the other Australian species, *C. Gunni*, by the size of its fruits. The stromata are produced in clusters of varying numbers, sometimes a hundred or more, on characteristic swellings on the attacked branches. Usually the smaller branches are affected and the cluster may encircle it. In larger branches it may be lateral. The stromata in a typical cluster may be in all stages from small round parchment-coloured objects, a millimetre or so in diameter, up to the fully grown structures 7 or 8 centimetres across. When not crowded they remain globular, but usually through mutual pressure they necessarily become pyriform. In the early stages they are homogeneous throughout, but are at length hollow, to a slight extent from a gelification of the interior but mainly owing to the growth of the peripheral layers. The inner surface of the mature fructification is regularly verrucose, each prominence representing an apothecium. When they have attained the diameter of approximately 1 centimetre, a regular reticulate pattern is apparent on the surface. Later, dehiscence takes place and the apothecia are exposed. These are rather angular in outline, yellow, and usually 3 millimetres across. The apothecia cover the stromata except for a small portion of the base, those at the apex are the first to dehisce. The sterile basal region is much smaller comparatively than that of *C. Gunni*. The asci are 170-210 micra in length, 17 micra in breadth, and eight spored, the ascospores globular and 15 micra in diameter. The paraphyses are filiform. The mature stromata are somewhat gelatinous and of the consistency of a *Huneola*. When disturbed they emit a cloud of ascospores. The ground beneath affected beeches is strewn in the season with freshly fallen and decaying *Cyttaria* fruits, which are quite conspicuous on account of their reticulations and the yellow colour.

In a dry atmosphere the stromata become leathery. On Mount Hobwee, however, they remain gelatinous and are forced off by their growing neighbours. Those that do not fall (being held by two or three growing adjacent) rot in the cluster, and the decay spreads to the younger ones, the apothecia of which may not have opened. The fungus responsible is a *Monilia*. It covers the affected fruits with a fine white mass of mycelium, tufted at first, the tufts finally confluent.

The branches of the beech beyond the *Cyttaria* galls are retarded in their growth, and the gall occasionally is at the end of the branch, the distal parts of which have been killed. At other times, though, a number of clusters of the fruits occur along the length of a branch, the general appearance, apart from the galls, is normal. The disease is certainly a serious one, but beeches, whether attacked or unattacked by *Cyttaria*, are almost invariably very decayed, and perfectly sound trees are exceptional.

The previously described species of *Cyttaria* are all edible. Darwin, in his Journal of Researches, described *C. Darwinii* of Tierra del Fuego as being eaten uncooked in its mature state. It has a mucilaginous slightly sweet taste, and a faint smell like that of a mushroom. The



Cyllaria septentrionalis sp. nov. (A) Cluster of stromata on branch of *Nothofagus Moorei* (a) immature, (b) mature, (c) small gall (B) Mature stromata (C) Ascus (a) Two thirds natural size, (b) natural size

Tasmanian *C. Gunnii* was eaten by the aborigines, and was known to the settlers as tree morell. The Queensland species has practically no taste or smell, but the stromata, especially when immature, are quite palatable

I am indebted to Mr, Mrs, and Miss Rankine, of Beechmont, for their help in obtaining the material from Mount Hobwee, to Mr C T White, F L S, Government Botanist, Queensland, for locating the fungus, and to Mr Clive Lord, F L S, Director of the Tasmanian Museum, for specimens of *C. Gunnii*

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The Stratigraphical Relationship of the Shales about Esk to the Sediments of the Ipswich Basin.

By DOROTHY HILL, B.Sc.

Research Scholar, Department of Geology, University of Queensland

Geological Map and Five Text-figures

(Read before the Royal Society of Queensland, 28th October, 1929)

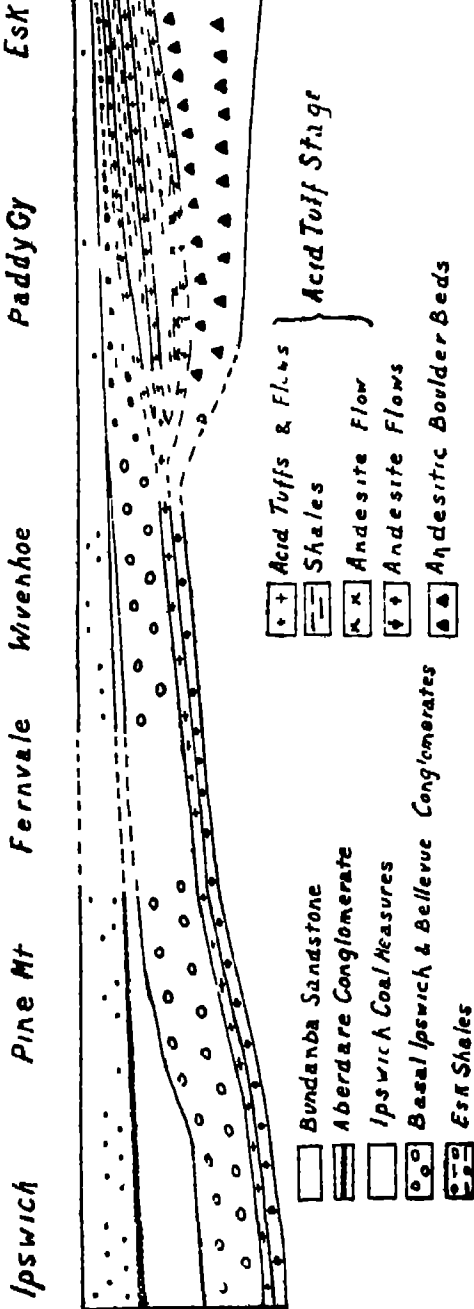
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I—INTRODUCTION AND OUTLINE OF CONCLUSIONS

The stratigraphical relationship between the rich plant-bearing Ipswich and Esk series has long been a problem calling for settlement. The two series are geographically close, palaeontologically and structurally rather similar, and yet lithologically different.

During the current year the author has been engaged on this fascinating problem and has obtained results indicating that the two series represent closely related phases in a shallow fresh-water basin, with but a slight chronological difference. For in effect the basal conglomerate of the Ipswich series changes laterally into the highest division of the Esk series, the Esk shales. The Ipswich coal measure shales thin out rapidly northward, and are missing from the basin north of Bellevue, where the overlying Bundamba sandstone comes to rest without apparent unconformity on the Esk shales.

DIAGRAMMATIC REPRESENTATION
of
LATERAL RELATIONSHIPS.



TEXT FIGURE 1

II—PREVIOUS WORK

Very early in the search for deposits of industrial importance in Queensland, coals were discovered in the Ipswich area in 1843¹. Some time later seams with a rather greater percentage of volatile hydrocarbons were found to the west of Ipswich, at Walloon, and on the Darling Downs. In both localities the seams occurred in a freshwater series of soft sandstones and shales, consequently, the measures of both districts were written of as one formation—the Ipswich formation.

Gradually the superiority of the coals near Ipswich (due to situation and quantity) became evident, and W. E. Cameron was detailed by the Government to make a geological survey of the Ipswich area. By 1905 he found² that the Walloon coals were on a higher horizon in a conformable series than the Ipswich, the two being separated by a barren sandstone stage, the Bundamba sandstone. The Ipswich stage was then divided into two—(1) a very thick basal conglomerate, and (2) the coal-bearing beds, these latter were shales, sandy shales, and sandstones with coal seams at various horizons, all beds being markedly lenticular in character.

In 1910³ Dr. Marks continued Mr. Cameron's work eastward and south-eastward to the coast, and showed that the Mesozoics there were the lateral equivalents of those of the Ipswich basin. He found that no detailed comparison could be made, due to the lenticularity of the basin deposits, but that there was a division into three major groups equivalent to the Walloon, the Bundamba, and the Ipswich stages. There was no basal conglomerate, but Cameron in 1905 showed that the basal conglomerate along the northern boundary of the field thinned out towards Brisbane. Cameron had mapped⁴ at various places, towards the base of the basal Ipswich conglomerate, outcrops of an acid tuff. Dr. Marks mapped in detail a rhyolite tuff taking a definite course through Brisbane and southward, always at the base of the Ipswich beds.

Meanwhile odd coal seams and plants of an Ipswich facies had been reported from round about Esk, and in 1912 Dr. Marks⁵ visited the area to investigate coal prospects. These he reported of no economic value. But he came to the opinion that the age of the beds about Esk was Walloon, due to their geographical position with respect to the Ipswich series.

This, then, was the stratigraphical position when Dr. Walkom⁶ studied the collected Lower Mesozoic plant fossils of Queensland, and their literature. The material he worked on was chiefly drawn from the well-known Denmark Hill horizon at the top of the Ipswich coal measures, but small collections from many other localities of unknown horizon were also examined. Dr. Tillyard⁷ studied the insects from Denmark Hill, and both workers concluded that the Ipswich coal measures were Rhætic or Upper Triassic in age. The plants from about Esk seemed to belong on the whole to genera believed to be characteristic of the Jurassic. Consequently, it was not suspected that the correlation of the shales about Esk with the Walloon series was erroneous. Mr. Cameron was meanwhile still working in the Ipswich field, and in 1922 his latest

and most detailed map was published, unfortunately without a report. In this map Mr Cameron shows that he interprets the structurally complicated West Ipswich area as a N W -S E faulted anticline

Two new workers in Messrs Reid and Morton now entered the field. They followed the vertical strip of rocks in the West Ipswich area north past Pine Mountain to Fairney View. Quite close to this strip only slightly inclined Ipswich or Bundamba strata were to be found, and the vertical strip seemed to be devoid of the coal seams and shales so characteristic of the horizontal series.

These observations suggested to Messrs Reid and Morton an interpretation very different from Cameron's West Ipswich fault. They concluded that the vertical beds were an older series on which, after a violent orogeny, the Ipswich coal measures were deposited. Nevertheless, the flora of the vertical beds were all forms found in the Ipswich beds. This vertical strip they called the *Borallon series*. They traced it past Fernvale to Northbrook, where they mapped in the Esk series as unconformable on it.

The publication⁸ of their views gave rise to the interesting 'Borallon Controversy'⁹ which ended by their recognising¹⁰ the vertical strip of "Borallons" as due to the effect on the Mesozoic Ipswich and Esk beds of a very regular and strong folding and faulting movement, running N N W from Beaudesert to Goomeri.

Apart from the recognition of this strong line of movement their work had a distinct value in that the rocks of the Esk area were grouped¹¹ into an *Esk series* striking N W and dipping gently S W. This, they considered, consisted of three divisions —

- (1) A lowest series of andesitic agglomerates and andesitic flows, conformably overlain by—
- (2) The Esk shales and Bollevue conglomerates (lateral equivalents) with interbedded trachyte tuffs
- (3) The Esk trachytes were believed to represent the top of this series. These had earlier been assigned by Dr Richards¹², from general considerations, to a Tertiary age.

To the west this series was followed by a siliceous sandstone series which Reid and Morton regarded as a continuation of the Bundamba sandstone. They believed this to be separated from the Esk series by a slight unconformity, or at least a disconformity, represented in time by the extrusion of the Esk trachytes.

From stratigraphical considerations they believed the Esk series to be the equivalent of the Ipswich coal measures. This was supported by palaeontological considerations. In 1921-1923 Reid noted¹³ that the genus *Thamnia* was predominant in the Ipswich series, but did not occur in the Walloon of the type district. Here *Tamnopterus spatulata* was predominant, while it did not occur in the Ipswich coal measures. In their examinations of the Esk flora, Reid and Morton¹⁴ and Walkom¹⁵ found

Thinnfeldia predominant, while *T. spatulata* was absent. Consequently the Esk series was removed from the Walloon and equated to the Ipswich coal measures.

Knowledge of the geology of the Ipswich-Esk area was at this interesting stage when the author began work on it.

III—PHYSIOGRAPHY

The present topography of the area under consideration is decided by two factors —

- (1) The structural attitude and differential hardness of the Mesozoics, causing erosion into forms relating to those structures.
- (2) The meanderings of the mature Brisbane River.

The effects of (1) are quite simple and obvious, more so for the Esk series than for the Ipswich, since only in the town of Esk itself, where the country is quite flat, do Tertiary and later deposits obscure it, while many Tertiary and superficial deposits overlie the Ipswich series in the type district.

Just south east of Esk, the Esk shales outcrop strongly with very slight dips, and here (Fors 33, 84, 85, Par Esk) erosion forms, typical of gently dipping sediments, are noticeable.

South towards Tea Tree Creek the dips are steeper, with the result that long N W ridges due to the superior weathering resisting powers of the trachyte tuffs have been formed, broken only by streams flowing across the strike. Such streams, *e.g.*, Paddy Gully and Tea Tree Creek would therefore appear to be relics of an earlier system of drainage.

The lowest stage of the Esk series, the andesitic boulder beds, forms gently undulating ground.

Southwards the Esk shales change laterally into the Bellevue conglomerates, and the series becomes almost horizontal, pebbly ridges resulting. A residual capping of Bundamba sandstone forms the high ground of Wivenhoe Hill. East and west of a line from Northbrook to Fairney View there is a remarkable contrast in topography, due to the different weather-resisting powers of the Mesozoics and the schists of the D'Aguilar block. To the west the Mesozoics form low ground showing mature topography, to the east the older schists form highlands exhibiting the young topography of steep rugged hills and deep valleys. The basal Mesozoic andesite and trachytic tuffs form the foot slopes of these schist heights. South of Fairney View these igneous rocks become unimportant topographically, and the heavy basal Ipswich conglomerates form the foothills for the schist highlands along the northern boundary of the Ipswich coalfield. In some places the outline of these conglomerate foothills would suggest that they had been step faulted parallel with the junction with the schist, but there is as yet no geological confirmation of this.

The Ipswich coal basin itself has almost reached peneplanation.

This peneplanation has removed from view all except very superficial thicknesses of Tertiary sediments and basalts, so that the late Cretaceous or early Tertiary peneplain upon which they were laid down is now visible. Had uplift occurred instead of the downwarp causing this Tertiary sedimentation and consequent protection of the early Tertiary peneplain, it is probable that to-day the early Mesozoic topography would have been visible instead.

The physiography of the Ipswich coal basin is in quite marked contrast to that of the country further away from the schist mass, where erosion did not progress to peneplanation before the extrusion of the Tertiary basalts, e.g., in the Rosewood-Walloon coalfield, the basalts overlies Walloon sediments and erosion has left them standing as a capping to a young range of plateau type.

The effect of the meandering of the Brisbane River in the present topography, while much more interesting than the first factor, is less important, due to its localisation of action. Odd boulder beds are to be seen at various high levels near the present river, indicating early river beds. Somewhat later courses are to be found in the present alluvial flood plains of the river, and careful work should result in the collection of enough data for the elucidation of the complete history of the Brisbane River.

It is an important fact that the present Brisbane River course in the area examined closely follows the junction of the Mesozoics with the schist, and the meanderings crossing this junction are of small radius.

IV—SEQUENCES AND STRUCTURE

Under this heading it is proposed to describe in geographical order the various sections studied by the author, and to show how they are correlated one with another.

(A) ESK-PADDY GULLY AREA

Wherever outcrops are found under the flat alluvial sands on which the town of Esk is built, they are of shales and sandstones rich in fossil plants of a Mesozoic aspect. The general strike of these sediments is NW and they dip gently to the SW. In lithology the beds vary from olive-green shales to fine-grained light brown sandstones. When weathering *in situ* they become rather like the grey Ipswich shales in colour, but unlike them in texture.

The succession is well seen somewhat to the south east of Esk (Fors 33, 94, and 85, Par. Esk). Here they are almost flat (becoming steeper towards the Glen Rock intrusive*) and are capped to the south-west apparently conformably by a coarse red siliceous sandstone believed to be a northerly continuation of the Bundamba sandstone.

The Glen Rock intrusive and the Esk trachyte and their relations to the Esk sediments are described in the section on Igneous Activity.

The Esk shales are seen to be divided into two by the strong development of a greenish, compact, pebbly sandstone. The upper shales are well seen in Por 94, where they are remarkably fossiliferous*, many undescribed forms occurring. *Schizoneura* sp is perhaps the most characteristic fossil of this horizon. The pebbly sandstone may be traced with gradually steepening dips to Paddy Gully, where it forms a marked conglomerate horizon. The lower of the two shale horizons gives no good outcrops. It overlies in Por 85 an important trachyte tuff, which is associated with a fine silky grey shale band characterised by abundant *Ginkgo cf. magnifolia* Fontaine.

This tuff, here forming Wildcat Ridge, was traced continuously in the field to Paddy Gully, where it was possible to make a section across the Esk series by walking along the boundary fence between the parishes of Esk and Wivenhoe. The new post holes gave good indications of the underlying rocks.

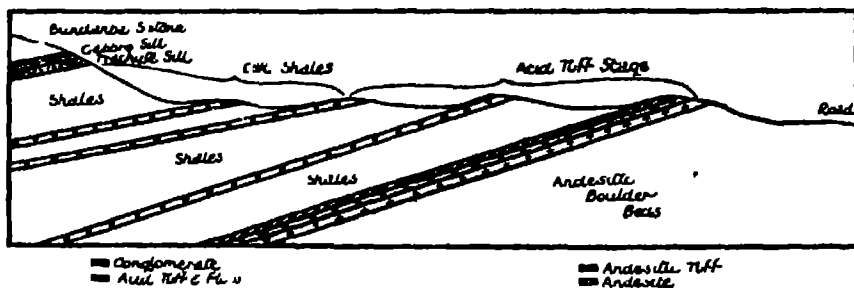


FIGURE 2 — SECTION ACROSS HILLS TO SOUTH OF PADDY GULLY

Nowhere was an outcrop giving the dip found, but in the author's opinion it is about 15° SW.

The section was begun from the west on the coarse compact red siliceous sandstone believed to be Bundamba. Between this and the Esk series there occurred (on the north bank of the gully) a gabbro sill and a hornblende porphyrite sill†, the gabbro sill being between the Bundamba and the hornblende porphyrite sill.

A small "valley" of greenish shales and soft pebbly sandstones follows the hornblende porphyrite (on the south bank of the gully) and then a low ridge of a hard compact pebbly sandstone, the same horizon as that seen in Pors 33 and 94, Par Esk. The next valley between ridges 2 and 3 was due to the softness of a set of shales and sandstones with fine conglomerates. For these parts of the Esk series the author wishes to propose the name *Esk shales*, since, as above described, they form the bedrock of the town of Esk.

* Lists of fossils from these and other localities are given in Section VIII.

† The significance of this post-Bundamba intrusion is referred to in the section on Igneous Activity.

The next ridges, 3, 4, and 5, were due to the hardness of three beds of trachyte tuffs with accompanying trachyte flows, descriptions of which will be found in the section on Igneous Activity. Ridge 3 represents the continuation as traced in the field of the trachytic tuff of Wildcat Ridge (Por 85) and here again it is associated with *Ginkgo cf. magnifolia* Fontaine.

The valleys between ridges 3 and 4 showed outcrops of soft pebbly sandstones and conglomerates, with interbedded shales.

The slope east down from ridge 4 showed soft conglomerates and sandstones. The slope up to ridge 5, however, showed first an andesitic tuff, then an andesitic flow, and then, forming the crest of the ridge, a strong trachyte flow interbedded with trachytic tuffs.

This part of the section the author proposes to call the *acid tuff stage*.

The section from ridge 5 to the road was over a peculiar stage, called by Reid and Morton an "andesitic agglomerate." The present writer prefers to call it the "*andesitic boulder beds*" since the term agglomerate implies a pyroclastic origin, to demonstrate which there is here no evidence. The andesitic boulder beds consist of boulders of andesite and felspar porphyry only set in a greenish matrix which macroscopically looks tuffaceous, but which has never been found fresh enough to section. The boulders in some localities, e.g., Deep Creek, are nearly all rounded, while in others they are nearly all angular, the latter occurrence is the more usual. The size of the boulders is on the average 3-6 in., but 3 ft. masses have been seen. The writer has found no interbedded andesitic flows in the material, but at one locality—Deep Creek—she has seen interbedded greenish shales.

To date the author has thought of no reasonable mode of origin for these most peculiar boulder beds, which are believed to represent the base of the Esk series.

The Esk series is now seen to consist of—

Esk series	Esk shales	Upper shales
		Compact pebbly sandstone
		Lower shales
	Acid tuff stage	Trachytic tuff
		Shales, sandstones, conglomerate
		Trachytic tuff
		Shales, sandstones, conglomerate
		Andesitic tuff
		Andesitic flow
	Andesitic boulder beds.	

No unconformity is to be found within this series.

(B) MOOMBRA-BELLEVUE-WIVENHOE AREA

South-east from Paddy Gully the acid tuff stage was traced continuously through Tea Tree Creek to Moombra, where from a shale

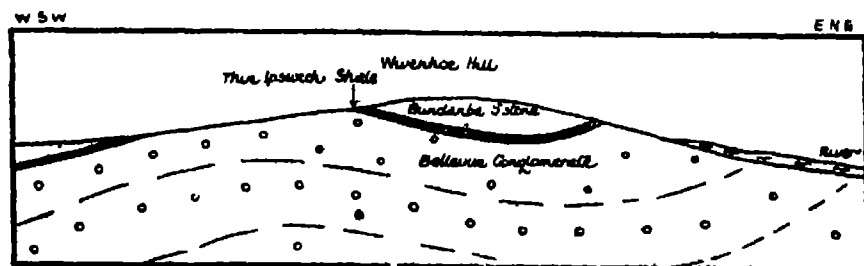
interbedded with the top tuff an important flora has been collected and has been described by Dr Walkom¹⁴

Thus acid tuff stage was further traced ESE to the Brisbane River, but not across the river. Mr Morton informs the author that the same tuffs do occur there, however.

The continuity southward of the Esk series has been traced by Messrs Reid and Morton in 1923 in a more accessible district, and in a more interesting portion of the series i.e., in the Esk shales, and the field work forms an interesting study in lateral lithological variation.

It has already been noted that the Esk shales were much coarser at Paddy Gully than about Esk. Traced still further to the south-east, they get coarser and coarser as their dips flatten out and the stage thickens, until in the section between the top of the acid tuff stage at Moombra and the Bundamba sandstone to the south they have changed so much lithologically as to warrant a new name for the same stage—the *Bellevue conglomerates*. These consist of shales and sandstones interbedded with beds of coarse conglomerate, the sandstones becoming predominantly of a fine brown feldspathic type, although green shale and grit beds are important. The pebble beds are green or grey in colour. The pebbles of this conglomerate are largely of andesites, green cherts, and a grey indurated grit, while jaspers, quartzites, trachytes and rhyolites are also represented in small numbers. In this section the beds strike NW and are almost flat, the dip being about 3° SW.

Towards Wivenhoe Hill the beds dip from all sides under an outlier of Bundamba sandstone of lithology similar to that already described, but from which they are separated by a slight thickness (50 ft) of soft shaley sandstones. Fossils have been collected from the top of the Bellevue conglomerates from two horizons at the foot of this outlier of sandstone—one half way up the road on the northern slope of the hill (Por 42, Par Wivenhoe) and the other in Sheep Station Creek (Pors 74 and 36). The writer believes the first of these to be the lower, from structural considerations, although she can produce no direct field evidence.



TEXT FIGURE 3—DIAGRAMMATIC SECTION THROUGH WIVENHOE HILL

As one approaches the junction with the schist on the east, the proportion of sandstones and shales gets smaller. On the Northbrook

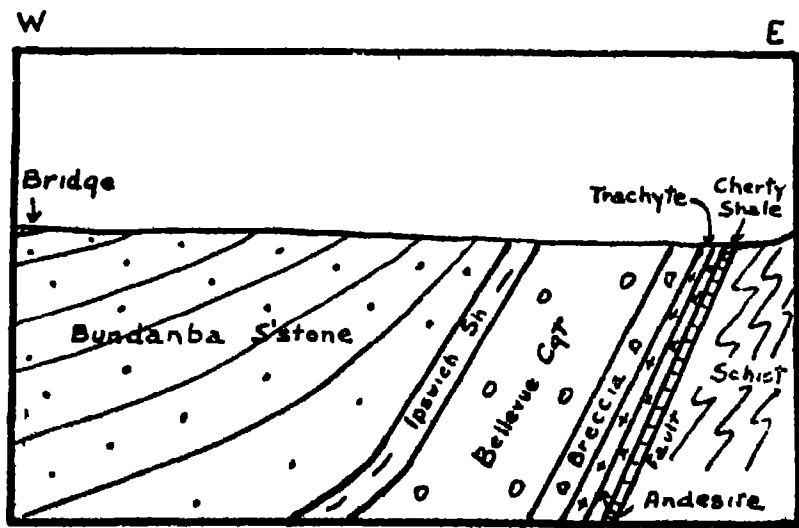
reach of the river there are no shales and sandstones of importance, while the pebbles appear to be all either green or grey. The relationship of the Wivenhoe Hill capping of Bundamba sandstone to the underlying Bellevue conglomerates may be seen in Text-figure 3

(c) WIVENHOE-FERNVALE AREA

The Bundamba sandstone capping of Wivenhoe Hill may be traced eastwards along the banks of the Brisbane River past Wivenhoe bridge, and along to the point on Portion 68 where the river turns back on itself. A diagrammatic section showing the relationships from Wivenhoe bridge eastward to the schist is seen in Text figure 4

East from Wivenhoe bridge the coarse siliceous current-bedded brown sandstone has gradually steepening dips, till it is about 70°. Then a change in lithology occurs, and soft felspathic shaley sandstones, alternating with shales carrying macerated plant remains and containing a few carbonaceous seams, follow. This finer, softer development would not be more than 200 ft thick, and the author regards it as the thin northerly development of the *Ipswich coal measure series*, which gradually thins out going north from the Ipswich coal field. These have a dip increasing towards the east from 60°-80°, and they are followed just at the turn in the river by a heavy conglomerate series, the *Bellevue conglomerate* consisting of vertical conglomerates and interbedded greenish shales and grits. One of these fine green shales, in Por 52, Par Burnett, was remarkably fossiliferous, and a good collection was made. This shale was almost at the base of the Bellevue conglomerate.

The conglomerate was followed further to the east by about 50 ft of a breccia in which the fragments were chiefly quartzites which possibly represented a shore line breccia, then representatives of the acid tuff



TEXT-FIGURE 4.—SECTION EAST FROM WIVENHOE BRIDGE.

stage of the Eak series in the shape of trachytes and trachytic tuffs, and an andesite and andesitic tuff were obtained, followed by a fine green cherty shale. This latter seemed in places to be separated from the schist by a peculiar brecciated rock which Mr Denmead* suggests as a fault breccia. This is followed by the Fernvale series of the Brisbane schists.

All the beds had a constant N W - S E strike, due to the strong N W - S E faulting.

Alluvium intervenes between this section and the Fernvale outcrops, nevertheless the lithology of the acid tuff stage leaves no doubt that the series continues to the south east beneath the alluvium.

(D) FERNVALE-FAIRNEY VIEW BELT

Geographically, this belt is a connecting link between the areas of outcrop of the type Ipswich and Eak series. It is a narrow N W - S E striking belt of vertical igneous rocks and interbedded sedimentaries, and has a faulted junction with the schist to the east. This fault is referred to as the Great Moreton fault.

The igneous rocks are acid tuffs, trachytes, and andesites of a type exactly similar to those beneath the Bellevue conglomerates in the Wivenhoe section. They are therefore regarded as the chronological equivalent of the acid tuff stage. Here, however, they do not appear to be associated with conglomerates like those at Wivenhoe or Mt Crosby. The thin sediments with which they are interbedded are all greenish in colour, being chiefly grits with some fine pebble beds and some shales of so fine a nature that they have been chertified.

This acid tuff stage forms the foothills to the schist highlands, and it is succeeded immediately to the west, along a line apparently approximately parallel to its junction with the schists, by a low sandy plain derived from the weathering of an underlying sandstone series.

This sandstone series is the Marburg sandstone stage of Mr Reid¹⁷. The beds of this stage vary rapidly in lithological character, yellow felspathic and micaceous flagstone types being associated with white very siliceous grits and with coarse ferruginous sandstones. The strike is N W and the dip gently S W, the maximum dip reading obtained being 15° S W on the road west of Portion 176, Parish North. Where this sandstone stage is found in closest association with the acid tuff stage, i.e., in the railway cutting in Por 77, Par North, where outcrops are only 50 yds apart, it is almost horizontal.

In this Marburg sandstone stage Mr Reid has found *Tamnopterus spatulata* and *Cladophlebis australis*, fossils diagnostic of the Walloon series, on the road between Por 191, Parish North, and Por 328, Parish Walloon.

We thus have, if the sandstones lying against the acid tuff are of the same series as those containing these fossils, almost horizontal Walloon

* Verbal communication

sandstones lying against the vertical acid tuff stage in a line of junction which is apparently approximately parallel to the junction of the acid tuff stage with the schists

Of the various explanations which arise to explain these peculiar relationships, two seem most probable —(1) that there has been a Walloon overlap on to strata already affected by the Great Moreton fault, or (2) that a sister fault to the Great Moreton fault has dropped down the Walloon (Marburg) strata against the acid tuff stage, cutting out the Bellevue conglomerate, the Ipswich coal measures, and the Bundamba sandstone. The latter interpretation is the one followed in the map appended.

Whether such a fault is present, or whether the junction line represents the original shore line of the Walloon lake, it would seem to be impossible to prove on the field evidence, as every available outcrop has been visited without satisfaction being obtained.

This obscuration is unfortunate in our examination of the relationship between the Esk-Ipswich series, for it obscures all but the lowest part of the connection between them

(E) SAHL'S POCKET

East of Fairney View railway station the Brisbane River makes the most important change in its course, turning from a general S E direction to a general E -W one, meandering across the junction of the Ipswich basal conglomerate with the schist. Sahl's Pocket is that particular meander enclosing the basal Ipswich just at the turning point.

In the Pocket it was found that the junction of the Mesozoics with the schist was an ordinary unconformity, and not a fault. The schists strike N N W as usual, but the Mesozoics lie on them with the gentle inclination of 20° S S E striking E N E -W S W.

A link is established with the Esk series by means of the acid tuff stage which here reappears in Por 1 with its characteristic trachytes and trachytic tuffs, and andesites, which rocks have a remarkable similarity to those of the Fernvale-Fairney View belt, a vesicular andesite being particularly useful in this equation. The acid tuff stage is separated from the Fernvale series in P P 1 by a small thickness of a heavy conglomerate in which the pebbles were of a greenish-grey colour reminiscent of the Bellevue conglomerate in the Northbrook reach.

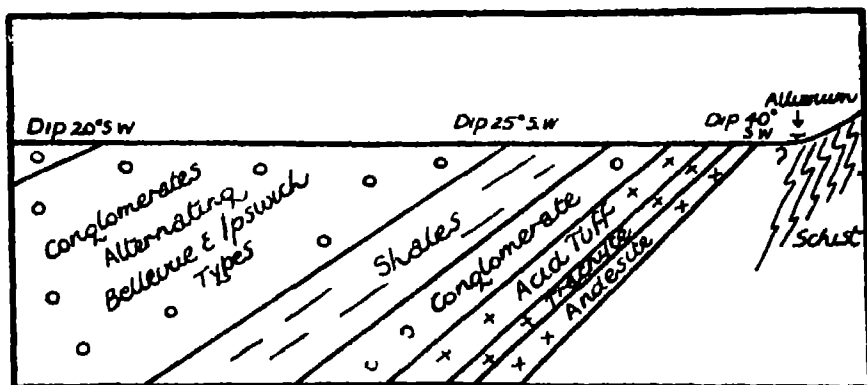
Succeeding the acid tuff stage in the same portion is an important conglomeratic formation, of a surprising thickness. Like the Bellevue conglomerates and basal Ipswich conglomerate it consists of lenticular beds of grits, sandstones, and shales, interbedded in the pebble beds. But in lithological type it is intermediate between these two, for the pebbles are a mixture of the greenish andesites, cherts, and grits characterising the Bellevue conglomerate, with the rhyolites, trachytes, and jaspers characteristic of the Ipswich basal conglomerate. The interbedded-

sandstones and shales also vary from the greenish grits, greywackes, and shales of the Esk-Bellevue type, to the brownish and greyish arkosic types characteristic of the basal Ipswich in its type section at College's Crossing. The lowest part of the conglomerate in the extreme westerly outcrop showed the characteristic lithological features of the Bellevue conglomerates of the Northbrook reach, this character decreased rapidly going up the series, and also geographically to the east.

A beautiful section may be seen on the river bank in Por 4, where the whole sequence is well exposed from the basal andesite to well up in the conglomerate stage.

S E

N W.



TEXT FIGURE 5 - RIVER SECTION, SAHL'S POCKET

Here the beds strike N 30° W, and in the south, where the section was begun, they dip at 20° S W, increasing to 40° at the junction with the schists. There was no evidence to show whether the junction was faulted or not, as a soft soil deposit separated the andesite from the Fernvale series jaspers.

The shale (250 ft) in the above section is a new development, which is seen again at Mt Crosby.

(F) PINE MOUNTAIN AREA

The problems of the geology of the Pine Mountain area are largely that of the faulting which has caused the Pine Mountain inlier. This Pine Mountain mass is composed of the Fernvale series, and is entirely surrounded by the southerly extension of the basal Ipswich formations seen in Sahl's Pocket. The junction between a rhyolite tuff and the schist on the northern boundary of the inlier appears to be a normal unconformable one, as does the eastern boundary, where heavy flat-lying basal Ipswich conglomerates lie against the schist. However, the western and southern boundaries are faults, for the members of the acid tuff stage, and the basal Ipswich conglomerate, are vertical and the junction is a straight line, although the topography of the country is far from flat.

The junction of the basal Ipswich conglomerate with the schist along a line from Por 494 to Por 386, Par Brassall also appears to be faulted, as the Ipswich strata are suddenly uptilted on approaching the boundary

As the northern and eastern boundaries of the Pine Mountain inlier are unfaulted, and as the junction between the Ipswich and schist in Sahl's Pocket is a normal unconformable one, it appears that there were at the beginning of Mesozoic times troughs between the Pine Mountain inlier and the schist to the north-east. Hence the Pine Mountain faultblock, with its peculiar angular outline, was probably originated in pre-Ipswich times, while posthumous faulting occurred along its western and southern boundaries in post-Ipswich time.

This fault along the western boundary of the inlier may be seen on the map to be continuous with the Great Moreton fault dropping the acid tuff stage against the schist from Fairney View to Northbrook, and it is believed to continue for many miles in a N N W direction.

To the west of Pine Mountain a good vertical section from the acid tuff stage (which is represented by tuff on the northern part and andesite on the southern) to the Aberdare conglomerate at the base of the Bundamba series may be seen, and one is impressed by the thinness of the Ipswich coal measures representative here relative to its thickness actually in the Ipswich coal measures basin. Hence the extreme thinness of the coal measures series in the Wivenhoe section and its absence from the Paddy Gully-Esk sections is not surprising.

An important sister fault to the Great Moreton fault runs from N E of Wanora in a S E direction through Wulkuraka. The nature of this fault, which it is proposed to call the Borallon fault, is believed to be very similar to that of the West Ipswich fault of Cameron, both being faulted anticlines with a strong downthrow to the west, while the West Ipswich fault was the earlier of the two.

It seems that while the Great Moreton fault does not affect the Walloon strata, both the West Ipswich and the Borallon faults do, and the junction of Walloon and Bundamba strata which in this southern part of the area appear conformable, is apparently a straight line junction¹⁸ due to their attitude induced chiefly by the Borallon fault. This Borallon fault continued northward may be the reason for the junction anomaly of the Fernvale-Fairney View belt.

The present section is to be regarded only as a preliminary account of the Geology of the Pine Mountain area, for the author intends to complete the field work and to publish the results in a paper entitled "The Structure of the Pine Mountain Area."

(g) COLLEGE'S CROSSING-MT CROSBY-IPSWICH AREA

This area serves as the section showing the whole sequence of the sediments of the Ipswich basin as typically developed. Mr Cameron

and Messrs Reid and Morton have traced the continuity of the basal Ipswich conglomerates from Sahl's Pocket through the Kholo Pocket and along to Mt Crosby and College's Crossing

The basal Ipswich conglomerate here has its typical pebble content—more than 80 per cent of the pebbles are made up of rhyolites and grey-wackes, and other types include trachytes, jaspers, quartzite, aplites, and various metamorphic rocks—andesites and green chert pebbles (the Bellevue type pebbles) are singularly rare. The interbedded sandstones are of two types—brown and grey. The brown types often contain traces of equisetalian fossils, and are usually flakey. The grey are arkosic in nature, constituents being fresh biotite, quartz, and fresh felspars.

Representatives of the acid tuff stage are seen in this area at various outcrops.

Two good sections are visible at Mt Crosby, one on the road from Ipswich, and the other on the river bank at the weir.

The road section is the one reported on by Mr O. A. Jones¹⁰. Here the conglomerates lie conformably on fossiliferous, fissile green shales carrying an interbedded band of acid tuff similar in thin section to the Brisbane tuff. Lower than these occurs a basic flow of large extent referred to by Cameron and by Jones as a tertiary basalt. This the author regards as a representative of the basal andesite seen from Fernvale southward. A similar section, but lacking the tuff, is seen on the river bank at the weir. Here the "tertiary basalt" has been sectioned, and is shown to be unmistakably related to the basal andesite of Sahl's Pocket.

The series in this sector has an average E-W strike, with a dip south from 20°–10°. It is conformably overlain by the thick sediments of the Ipswich coal measure series and the Bundamba sandstone. Between these two occurs the Aberdare conglomerate, a horizon which is persistent in the Ipswich coal basin, but unrepresented elsewhere in South-Eastern Queensland.

Actually within the schist mass to the north of Mount Crosby is a small outlier of fine-grained red shales with *Thunfeldia odontopteroides*, which represents a small separate basin in the schist.

When traced easterly along the northern margin of the Ipswich coal basin the basal conglomerate thins out, and the percentage of rhyolite pebbles become less. It peters out altogether to the east of College's Crossing, and the shales of the Ipswich coal measure series lie directly on the schist.

A new but transient conglomerate horizon reappears, however, at Pullen Vale. It contains very few rhyolite pebbles and its pebbles represent rock types of the schists at Brookfield, from which it has evidently been derived.

(H) BRISBANE AREA

In the Brisbane area the Ipswich coal measure shales (here not carrying payable seams) lie for the most part directly on the schist. However, running through Brisbane, at the base of these shales, is a representative of the acid tuff stage, namely, the Brisbane tuff, which has been described by Mrs. C. E. Briggs²⁰

In the Aspley district a series with a typical Esk flora and of typical Esk shale lithology occurs associated with the tuff. Here also, it appears that the Esk facies is older than the Ipswich, which is represented by basal grits in the Nundah quarries.

V—IGNEOUS ACTIVITY

The earliest igneous activity in Esk-Ipswich times was that in which the lowest stage of the Esk, the andesitic boulder beds, was formed. These consist of rounded or angular pebbles or boulders of only two lithological types set in a homogeneous matrix. Porphyritic andesites form the greater number of the pebbles, and in the hand specimens all the andesites seem to be distinctly related to one another, the average appearance being of glassy phenocrysts of felspar set in a fine-grained grey matrix. The second type of boulders is of a more coarse-grained felspar porphyry, the phenocrysts of felspar being pink.

The dark grey-green matrix is usually very weathered, and no piece has been got fresh enough to section. However, its general appearance suggests an andesitic tuff, well formed crystals of plagioclase being often distinguishable.

The arrangement of the pebbles in the matrix is interesting. Very rarely do two pebbles touch one another. They seem to be spaced at equal distances apart, small pebbles lying side by side with huge boulders. Some localities show nearly all rounded pebbles, other nearly all angular ones. The writer has never seen any interbedded andesite flows or tuff beds, but at Deep Creek, where the boulders were nearly all rounded, fine greenish unfossiliferous shales were locally interbedded.

The author has not yet formulated a hypothesis of origin capable of successfully explaining all these facts.

These beds are formed only in the most northerly section of the basin examined, and do not occur south of Northbrook. They are overlain, apparently conformably, by the next stage of the Esk, also igneous, the acid tuff stage. This has representatives all over the basin examined, and south of Northbrook forms the lowest stage of sedimentation.

In the type Paddy Gully section, there are three trachyte flows and one andesite, each accompanied by tuffs, the sequence being from earliest to latest, andesitic boulder beds, trachyte, andesites, sediments, trachyte, sediments, trachyte.

The trachytes are all very similar to one another in the hand specimens, consisting of phenocrysts of sanidine and/or an opaque felspar.

in a fine-grained limonitic groundmass. The associated tufts are very fine in grain, compact, hard, and yellowish and sometimes silicified. At times, however, they become quite gritty, or pebbly, or even conglomeratic, evidence of deposition under water. Exposure has caused them to weather into rectangular fragments, which form the tops of long ridges and carry a characteristic vegetation.

In the southern part of the area, the acid tuff stage has rhyolitic representatives, *e.g.*, around Pine Mountain, at Mount Crosby, and the Brisbane tuff.

Whether the andesites of the basin south of Northbrook which occur, except at Fairney View, below all the acid extrusives, represent the andesitic boulder stage or the andesite of the acid tuff stage, has not been ascertained, but all three developments are obviously very closely related. Thin sections of the andesite from Mount Crosby weir and Sahl's Pocket show phenocrysts of plagioclase and hornblende in a fine-grained andesitic groundmass in which abundant calcite is to be found. The ferromagnesian minerals are weathered to chlorite. The richness in calcite is characteristic of the andesites of this stage. The andesites from Fairney View, Fernvale, Wivenhoe, and Northbrook are indistinguishable in the hand specimen from those of Sahl's Pocket and Mount Crosby weir.

The next stage of the Esk, the Esk shales (= basal Ipswich conglomerate) is free from igneous activity. But more than 50 per cent of the boulders of the conglomerate are of igneous rocks, mainly rhyolites and andesites. Their derivation is as yet uncertain.

The Ipswich coal measure series and the Bundamba series are also free from contemporaneous igneous rocks. In the Esk area, however, there are two acid igneous masses of interest. One of these, Glen Rock, is a fine-grained rhyolite described by Dr Richards¹, and is definitely intrusive into the Esk shales, which are indurated about its margin, strike in conformity with its outline, and dip steeply away from it.

The other mass, known as the "Esk trachyte," has given rise to controversy². The author believes it to be a laccolitic mass intruded between the Esk shales and the Bundamba sandstones in post-Bundamba (probably Tertiary) times, on the following evidence —

- (1) The Esk shales which surround the mass have an indurated appearance, and dip generally with no constancy of attitude, towards the igneous mass.
- (2) The mass itself is intermediate in texture, with short, broad phenocrysts of felspar, and a few odd badly shaped phenocrysts of hornblende set in a fine-grained melanocratic matrix. The name hornblende porphyrite would describe the material in thin section better than the name "trachyte."

- (3) It is capped by a small patch of sandstones and sandy shales lithologically similar and with similar dip to the Bundamba sandstones overlying the Esk shales further west. These sediments do not appear indurated.
- (4) The weathering shells of the igneous rock give an appearance of conformable bedding with the bedding of the sandy shales and sandstone bands.
- (5) Rocks exactly similar in thin section occur in a similar stratigraphical position in Paddy Gully. Here they are surely intrusive, for a sill of coarse gabbro lies between the porphyritic sill (?) and the Bundamba sandstone.

On the Sim Jue Creek road in the Northbrook area there occurs a granite which the author believes intrusive into the Triassic sediments there. The geology of the Northbrook area is, however, to be described in a separate paper in conjunction with Mr A. K. Denmead, M.Sc.

VI—THE EVOLUTION OF THE BASIN

In other parts of the world, particularly in England, emphasis has lately been placed on two important principles. First, that in any basin, more especially a shallow one, lithological phases need not necessarily be constant, but may be transient, migratory, or laterally varying. And second, that conglomerates take on certain characteristic features according to their mode of origin. The application of these two principles to the present problem has given very interesting results, which are discussed hereunder.

Extent and Shorelines

That part of the Moreton basin discussed in this paper consists geographically of two parts, due to the shape of the D'Agular schist block, one, a northern section developed to the west of the block between Esk and Fairney View, and the second, a southern section developed to the south of the block between Fairney View and Brisbane.

Mr Cameron²³, when he first studied the Ipswich coal field, thought its northern boundary represented a fault junction with the schist, because of its very straight, angular nature. More detailed work, however, led him to retract this decision²⁴ and to adopt the view that the northern boundary represented the original shore line of the basin. For the Mesozoic sediments had only very slight dips at this junction, there were no cataclastic effects of faulting visible, and there were no outliers of basin sediments on the D'Agular block.

With this latter interpretation the author agrees, but there still remains the necessity to explain the somewhat unusual angular junction. Dr Bryan suggests²⁵ that these angular schist shore cliffs may represent a pre-Mesozoic fault scarp. Scarps are transient things, and unless protected by quick covering by sediments their nature is soon lost by erosion levelling. In the present instance, early Mesozoic sedimentation may have preserved the scarp, consequently the fault must have occurred,

—if at all—very soon before this sedimentation, and its age may be placed as post-Permo-Carboniferous. As yet no evidence of post-Triassic or rejuvenation faulting has been found along this boundary.

As to whether the junction of the Mesozoics with the western edge of the D'Agular block is a shore line or not, evidence is not so definite. For here a very strong post-Mesozoic fault has occurred dropping down the Mesozoics relative to the block. No outliers of Esk sediments occur on the block, however, but this is not to say that they were never deposited there. Should the Great Moreton fault prove to be a rejuvenation of a pre-Mesozoic fault complementary to that of the southern boundary of the D'Agular block, then most probably the western boundary was also a shore line.

Depositional Migration in the Basin

The andesitic boulder beds of the Esk series probably form a continuous²⁶ belt of constant lithology stretching for a distance of nearly 90 miles from Kinbomby to just north of Bellevue, where they still seem to be well developed. Their absence from all favourable sections south of Bellevue, then, is very remarkable. It cannot be explained as due to suppression by the Great Moreton fault, for in the unconformable junction of the Mesozoics with the schist at Sahl's Pocket they are still lacking.

It is possibly represented by the andesite at the base of all sections from Wivenhoe to Mount Crosby. Also, while the acid tuff stage does not entirely disappear with the andesitic boulder beds, it has only a very thin representative south of Bellevue, no sediments except thin bands of fine green cherty shales are associated with it.

Thus during the deposition of the andesitic boulder beds and the acid tuff stage, heavy sedimentation was confined to that part of the basin ending at about Northbrook, while the basin south of Bellevue was an area of very slight or no sedimentation. Each of these three changes independently suggests that land conditions were dominant in the southern portion. That is, the basin south of Bellevue was not inundated until the andesitic boulder beds and Esk acid tuff stage had been deposited to the north of Bellevue.

Period of Deposition of the Esk Shales, Bellevue Conglomerates, and Basal Ipswich Conglomerates

After the deposition of the acid tuff stage, conditions in the basin changed. In the Esk area fine shales were developed which have been traced in the field by Reid and Morton²⁷ and seen to pass laterally to the south into the Bellevue conglomerates (one of the three heavy conglomeratic deposits of this new phase of deposition). These Bellevue conglomerates have an undetermined thickness, but one much greater than 100 ft which is the maximum thickness for shore-line deposits as determined by Barrell. According to Barrell's work, therefore, they must be either estuarine or fluvial in origin. The former origin seems more satisfactory here.

Many different types of very rounded pebbles are represented, and it may be possible to discover whence the rivers flowed by a detailed study of the pebbles, *e.g.*, one method would be to plot the progressive percentage of the various types in the different localities, to see whether the progression was also geographical.

What was deposited above the acid tuff stage in the Fernvale-Fairney View area is unknown, because of the position of the Marburg sandstone stage.

In Sahl's Pocket, however, an (estuarine ?) conglomerate even more notable than the Bellevue conglomerate is formed between the acid tuff stage and the Ipswich coal measures. This is continuous with the similar conglomerate at Mount Crosby which thins out towards College's Crossing, and disappears altogether about a mile to the east of the crossing. This conglomerate may represent a composite fan from more than one river flowing into the Ipswich basin in Esk shale times from the D'Aguiar block, or it may be the simple fan of one very large river (perhaps the westerly migrating ancestor of the Brisbane River).

The basal conglomerates as developed at Kholo, Mount Crosby, and College's Crossing definitely pass under the Waterworks seam, the basal seam of the Ipswich coal field. Therefore, the sediments of the Ipswich coal basin cannot be the lateral equivalents of these conglomerates, but must represent sediments deposited on top of them. This change in deposition is probably to be explained by the gradually lessening gradient causing the currents to slacken and to be thus incapable of carrying coarse sediments. Instead they spread fine sandstones and shales and drift-formed coal seams far out over the basin.

But while none of the fine sediments of the Ipswich coal basin near the northern boundary of the field could be explained as lateral equivalents of the conglomerates, those sandstones and shales between the tuff and the Bundamba sandstone in the South-east Moreton basin contain the lateral equivalents of these estuarine fans, as well as the lateral equivalents of the Ipswich coal measures.

In the area occupied by the Ipswich coal basin and its extension northward as far as Fairney View some sudden alteration in conditions resulted in the formation of the transient Aberdare conglomerate. This was immediately succeeded by the strongly transgressive and immensely thick Bundamba sandstone, which has been traced from the Beaudesert region to Esk.

VII—EARTH MOVEMENTS

The earliest earth movement affecting the history of the basin would be the one causing its inception. Deposition seems to have begun first in the Esk-Bellevue part of the basin, so that it may be concluded that downwarp or downthrow affected this area first, and that movement causing the depression of the Ipswich coal basin occurred later. This later movement seems to have been accentuated, if not actuated, by the

strong fault forming the southern scarp of the D'Agular block, but whether the inception of the Esk-Bellevue part of the basin was accentuated or actuated by faulting along the present western scarp of the D'Agular block remains to be proved

After the deposition of the acid tuff stage the effect of the strong difference in level of the D'Agular block had resulted in the inception of a river or rivers forming the Bellevue and basal Ipswich conglomerate. The one feeding the basal Ipswich conglomerate seems to have become the more important by the time the gradient had been lowered sufficiently for the formation of fine deposits instead of coarse ones, for the Ipswich coal measure series spread west round the edge of the basin over the southern part of the Bellevue conglomerate, and east to Brisbane. Some slight alteration in conditions then resulted in forming the Aberdare conglomerate over a somewhat more restricted area than the Ipswich coal measure shales.

A sudden downwarp now caused the widespread transgressive horizon, the Bundamba sandstone. Then (if we accept a Walloon overlap), faulting occurred in the northern part of the area, and the acid tuff stage, basal Ipswich or Bellevue conglomerate, Ipswich coal measures, and Bundamba sandstones, were dropped down against the D'Agular block by the Great Moreton fault. Deposition of the Marburg sandstone stage then occurred, followed after a "slight uplift and a period of non-sedimentation and erosion"²⁸ by the Rosewood stage of the Walloon series. (If, however, we accept the view that a continuation of the Borallon fault caused the present relations between the Marburg stage and the acid tuff stage, then the Great Moreton and Borallon faults did not occur till after the deposition of the Marburg stage.)

Faulting along the West Ipswich and Borallon lines of disturbance then followed with the formation of the many N W - S E minor faults cutting the coal measures in the mining districts.

It will be seen that although all these major north-west faults appear to belong to the one fault system, it is believed that they were not contemporaneous, but that the order was —Great Moreton fault, West Ipswich fault, and Borallon fault.

A phase of rapid erosion ensued which was noteworthy in that the erosion was confined to the unstable area to the south and south-east of the angle of the D'Agular block with the formation of an early Tertiary or Cretaceous peneplain. Downwarp and renewed sedimentation in this area then occurred, with the deposition of the Tertiary basalts. Then another period of erosion followed, until to-day the (?) Early Tertiary peneplain is again visible.

That adjustment in this area of instability was not complete in Tertiary times is shown by the folding of Tertiary sediments about the old N W - S E axes.

The above interpretation of the area is indeed very far removed from current opinions. But it seems to be necessary to explain the new facts discovered during the author's work in the field. Though much has been done, much remains to be done, so that the final interpretation of the structure of the area may differ considerably from the one at present placed on it.

VIII — PALÆOBOTANY

Palaeobotanical data are presented in the form of the accompanying table —

SPECIES	LOCALITY
<i>Elatocladus plana</i> (Feist)	? 1, 13, 17, 31
Gymnospermous seed	1, 11
<i>Phanicopteris elongatus</i> (Morris)	11, 12, 31
<i>Bennettites</i> (<i>Williamsosnia</i>) <i>sp</i>	1
<i>Otozamites queenslandi</i> Walk	13, 31
? <i>Otozamites sp</i>	15, 39
<i>Nilssonia mortoni</i> Walk	10, 13
<i>Nilssonia reidi</i> Walk	11, ? 19
<i>Nilssonia eskensis</i> Walk	18, 31
<i>Nilssonia sp</i>	31
? <i>Nilssonia superba</i> Walk	11
(?) <i>Nilssonia sp</i>	9, 31
<i>Pterophyllum multilineatum</i> Shur	1, 22, 23
<i>Pterophyllum contiguum</i> Schenk	33
? <i>Pterophyllum nathorsti</i> (Sew)	13, 20, 33
<i>Pterophyllum abnorme</i> Eth	29, 31
<i>Pterophyllum nathorsti</i> Walk	11
<i>Pterophyllum sp</i>	10, 17
<i>Pseudoceras cathiensis</i> (Rich)	11, 12, 16, 19, 31, 33, 34, 40
<i>Podozamites</i> ? <i>lancoletatus</i> (L & H)	11
<i>Ginkgo antarctica</i> Saporta	1
<i>Ginkgo digitata</i> Brongn	1, 12, 19, 22, 24, 31
<i>Ginkgo cf magnifolia</i> Font	12, 14, 22, 31
<i>Ginkgo</i> ? <i>sibirica</i> Heer	9, 19
<i>Ginkgo sp</i>	11
<i>Ginkgo sp</i>	17
<i>Baiera simmondei</i> (Shur)	1, 19, 34
<i>Baiera bidens</i> (T Woods)	1, 11, 13, 19, 22
<i>Baiera ginkgoidea</i> Shur	1
<i>Baiera spirostachya</i> Shur	1
<i>Baiera tenuifolia</i> John	1
<i>Baiera sp</i>	31
<i>Baiera sp</i> .	.. 13
<i>Stachyopitys annularoides</i> Shur	1, 26
<i>Stachyopitys simmondei</i> Shur	1
<i>Dictyophyllum rugosum</i> L & H	1, 11
<i>Dictyophyllum davidi</i> Walk ..	33.
<i>Hausmannia buchu</i> Andrae .	35.
<i>Coniopteris deltoidea</i> Shirley .	28.

SPECIES	LOCALITY
<i>Cadophlebia australis</i> (Morr.) .	1, 3, 4, 10, 11, 12, 13, 14, 16, 22, 23, 27, 31, 32, 33
<i>Cladophlebia lobifolia</i> (Phill)	10, 11, 13, 19, 35
<i>Cladophlebia</i> sp	10.
<i>Cladophlebia</i> sp	.. 10
<i>Cladophlebia johnstoni</i> Walk	. 10, 31
<i>Cladophlebia roylei</i> Arber	1, 22, 29
<i>Todites williamsi</i> (Brongn)	10, 13
<i>Thinnfeldia feistmanteli</i> John	1, 3, 5, 6, 7, 9, 10, 11, 13, 17, 23, 26, 37, 38
<i>Thinnfeldia olontopteroides</i> (Morr)	1, 7, 10, 11, 12, 13, 15, 17, 23, 24, 30, 31
<i>Thinnfeldia lancifolia</i> (Morr)	1, 9, 10, 11, 12, 15, 17, 19, 23, 31, 33, 38, 40
<i>Thinnfeldia acuta</i> Walk	12, 23
<i>Thinnfeldia talbragarensis</i> Walk	8, 10, 11, 12, 15
<i>Thinnfeldia eskenensis</i> Walk	13, 31, 35
<i>Thinnfeldia</i> sp	9
<i>Dacnopsis hughesi</i> Feist	1, 13
<i>Asterotheca denmcadi</i> Walk	10, 13
<i>Asterotheca hillei</i> Walk	9, 11, 12
<i>Neuropteridium moombraenes</i> Walk	13, 31
<i>Tenopterus elongata</i> (Carr)	1, 7, 23, 24, 30
<i>Tenopterus tennison woodsi</i> Eth	1, 9, 11, 12, 14, 16, 17, 22, 24, 26, 36
<i>Tenopterus carruthersi</i> Ten Woods	26, 30, 32
<i>Tenopterus lenticuliformis</i> Eth	1
<i>Tenopterus dunstani</i> Walk	1, 25
<i>Tenopterus ? wainmanii</i> Feist	21
<i>Tenopterus crassinervis</i> Feist	11, 15, 18, 19, 27
<i>Anthrophyopsis grandis</i> Walk	10
<i>Sphenopterus superba</i> Shur	1, 9, 11, 12
<i>Sphenopterus lacunosa</i> Shur	1
<i>Sphenopterus eskenensis</i> Walk	36
<i>Sphenopterus ? peckii</i> Hallé	19
<i>Sphenopterus</i> sp	9
<i>Schizoneura cf. Africana</i> (Feist)	4, 10
<i>Schizoneura</i> sp a Sew	10, 11, 15, 17
<i>Schizoneura</i> sp	2
<i>Neocalamites cf. carreri</i> Zeill	1, 3
<i>Neocalamites harrisi</i> Schimp	1, 32
<i>Phyllothea australis</i> Brongn	1
<i>Equisetites rotiferum</i> T Woods	7
<i>Chiropterus</i> sp	. 9

Italicised numerals signify occurrences not noted in previous publications

Ordinary numerals signify occurrences noted in previous publications.

LOCALITY KEY.

1 Denmark Hill	22 Yeronga
2 4 ft coal seam	23 Petrie's Quarry, Albion
3 Bundamba	24 Campbell's Quarry, Albion
4 Ebbw Vale Colliery	25 Windsor Town Quarry
5 Dinmore	26 Nundah
6 Bremer Basin Colliery	27 Toombul
7 Trivoli	28 Shorncliffe, Sandgate
8 Por 366, Par Brassall	29 Redbank, near Mt Esk
9 Por 36, Par Wivenhoe	30 Mt Esk
10 Por 74, Par Wivenhoe	31 Road between Pors 155 and 157, Par Biarra
11 Por 42, Par Wivenhoe	32 Por 32, Par Northbrook
12 Por 52, Par Burnett	33 Por 28v, Par Biarra
13 Road between Pors 70 and 76, Par Wivenhoe	34 Coal Creek, near Esk
14 $\frac{1}{2}$ mile west of Esk P O	35 6 miles north of Esk
15 Por 94, Par Esk	36 Railway cutting, Ottaga
16 Por 33, Par Esk	37 Mt Brisbane R O, 5 miles north of Esk
17 Por 81, Par Esk	38 Kilcoy Range, above Crossbrook.
18 Por 85, Par Esk	39 Por 92, Par Esk
19 Por 24, Par Esk	40 Colinton
20 Por 32, Par Esk	
21 Ipawich	

Localities 1-20 are arranged in descending stratigraphical succession

Localities 21-29 represent unplaced horizons in the Ipswich-Brisbane area

Localities 30-40 represent unplaced horizons in the Esk area

Very little use has been made of palaeontology during the work for three chief reasons —

- (1) The flora collected represents only a very small percentage of the forms present on any horizon. The only horizon which is collected from with any degree of completeness is Denmark Hill
- (2) The unsatisfactory state of the palaeobotany of the world for detailed correlatory purposes
- (3) Faulty deposition of the plant remains, by which is meant that the plant fragments carried away and deposited within the basin by no means represent all the forms living even in the district which was the immediate source of the deposit

It will be seen that the stratigraphy will of necessity be used to solve palaeobotanical problems and not *vice versa*, in future work

Much palaeobotanical descriptive work remains to be done. The Esk shales are marvellously rich in fossils, which are well preserved in a colour which contrasts with the matrix. In Sheep Station Creek the tissue of the plant is preserved as a carbonaceous film, which could be treated by the latest palaeobotanical methods

IX —CORRELATION AND AGE

The following table of correlation for the Ipswich and Esk shales is satisfactory on the evidence so far to hand

IPSWICH AREA	ESK AREA
Bundamba sandstone	Bundamba sandstone
Ipswich coal measures	Period of no deposition
Basal Ipswich conglomerate = Bellevue conglomerate . . .	= Esk shales
Acid tuff and andesite*	= Acid tuff stage
	Andesitic boulder beds

This table shows how closely related the Ipswich coal measures and Esk shales really are. Florally (at the present stage of the palæobotany of the world) they may be regarded as one, and the whole flora compared with that of the rest of Gondwana Land.

The very close resemblance of the flora to that of the Molteno beds of the Karroo system of South Africa had led all palæontologists to place the two as of approximately the same age. Recent work by du Toit¹⁹ in South Africa has suggested that the Molteno flora is essentially Upper Triassic (Keuper) in age, and not Rhætic as formerly supposed. The Ipswich-Esk flora is therefore automatically to be regarded as of the same age, i.e., Keuper.

X —CONCLUSION AND ACKNOWLEDGMENT

In conclusion, it is to be stated that the working out of this complex area is by no means finished, although it is believed that the problem of the relationship of the Esk shales to the Ipswich coal measures has been correctly solved.

Very sincere thanks are given to Drs Richards, Bryan, and Whitehouse, who directed the author's interests into this fascinating study of ever-changing conditions, and who were always ready to discuss the various problems as they arose. No one realises more than the author the extent of the inspiration gained from them. Mr C C Morton gave many valuable field data, and Misses Buchanan, Ferguson, Holdsworth, and Hooper made sections of some of the igneous rocks.

* These andesites may represent the andesitic boulder beds

APPENDIX A

BIBLIOGRAPHY OF THE IPSWICH COAL MEASURES

In this bibliography, which is complete to the best of the author's knowledge, the following abbreviations are used —

A A A S	Australian Association for the Advancement of Science
A R D M N S W	Annual Report of the Department of Mines, New South Wales
A R D M Q	Annual Report of the Department of Mines, Queensland
A R G S Q	Annual Report of the Geological Survey of Queensland
G S Q P	Geological Survey of Queensland Publication
P L S N S W	Proceeding of the Linnean Society of New South Wales
Proc N Z Inst	Proceedings of the New Zealand Institute
P R S N S W	Proceedings of the Royal Society of New South Wales
P R S Q	Proceedings of the Royal Society of Queensland
Q Geogr Jnr	Queensland Geographical Journal
Q G M J	Queensland Government Mining Journal
Q J G S	Quarterly Journal of the Geological Society of London

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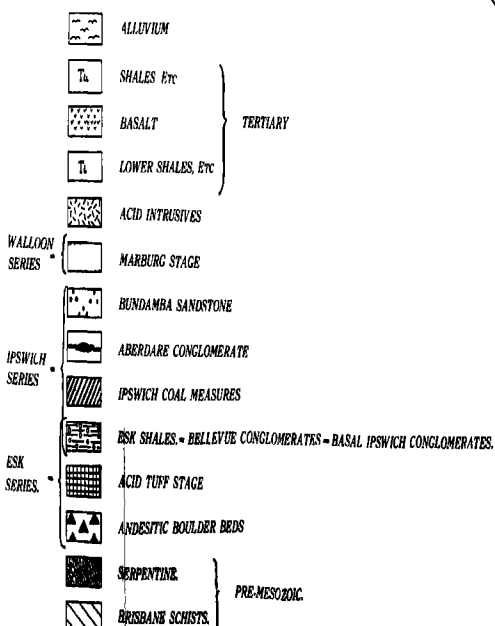
GEOLOGICAL SKETCH MAP
of the
COUNTRY BETWEEN
IPSWICH and ESK.

Scale 1:10,000
Scale in miles

LEGEND

	ALLUVIUM	
	SHALES Etc	} TERTIARY
	BASALT	
	LOWER SHALES, Etc	
	ACID INTRUSIVES	
	WALLOON SERIES	} MARBURG STAGE
	BUNDAMBA SANDSTONE	
	ABERDARE CONGLOMERATE	} IPSWICH SERIES
	IPSWICH COAL MEASURES	
	ESK SHALES - BELLEVUE CONGLOMERATES - BASAL IPSWICH CONGLOMERATES.	} PRE-MESOZOIC
	ACID TUFF STAGE	
	ANDESITIC BOULDER BEDS	
	SERPENTINE.	} PRE-MESOZOIC
	BRISBANE SCHISTS.	

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- 1926 O A JONES The Tertiary Deposits of Moreton District, S E Qld ,
P R S Q , vol 38, No 2
- 1927 W H BRYAN and Later Palaeogeography of Queensland, P R S Q , vol 38,
F W WHITEHOUSE p 103
- 1929 MRS C BRIGGS The Brisbane Tuff, P R S Q , vol 40, p 147

APPENDIX B

BIBLIOGRAPHY OF MESOZOIC ROCKS IN THE ESK DISTRICT

- 1901 L C BALL Notes on the Taromeo District, A R G S for 1900,
Q S Q P 159
- 1901 C F V JACKSON Mines near Esk, Q G M J , pp 466, 468, 469, 530
- 1906 L C BATT The Upper Brisbane Valley, Q G M J , p 470
- 1912 L C BALL Mines in the Parish of Taromeo, Q G M J , p 111
- 1912 I O MARKS Prospects of Coal at Esk, Q G M J , p 322
- 1912 F O MARKS On the Geological Age of S E Qld , Volcanic Rocks,
P R S Q p 139
- 1915 A B WALKOM Mesozoic Floras of Queensland, pt I (a), (b), G S Q P 252
- 1916 H C RICHARDS Volcanic Rocks of S E Queensland, P R S Q , vol 27, No 7
- 1917 A B WALKOM Mesozoic Floras of Queensland, pt I (c), G S Q P 257
- 1917 A B WALKOM Mesozoic Floras of Queensland, pt I (d), (e), (f), G S Q P
259
- 1918 A B WALKOM The Geology of the Lower Mesozoic Rocks of Queensland,
P L S N S W , vol 43, pt 1, p 37
- 1923 J H REID Note on the Walloon Jurassic Flora, P R S Q , vol 34,
p 108
- 1923 J H REID and Geology of the Country between Esk and Ipswich,
C C MORTON Q G M J , p 7
- 1924 A B WALKOM On Fossil Plants from Bellevue, near Esk, Mem Qld Mus ,
vol 8, pt 1, p 1
- 1926 H C RICHARDS Volcanic Activity in Queensland, A A A S (1924), p
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- 1928 A B WALKOM Fossil Plants from the Esk District, vol 53, pt 4, P L S
N S W
- The Murgon-Goomeri District*
- 1925 J H REID Geology of the Murgon Goomeri District, Q G M J ,
p 87

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The Royal Society of Queensland.

Report of Council for 1928.

To the Members of the Royal Society of Queensland

Your Council has pleasure in submitting its Report for the year 1928

Thirteen original papers were read before the Society and published during the year. Three public meetings were held. On 10th July, 1928, Dr C M Yonge, leader of the Great Barrier Reef Expedition, Dr Stephenson, and Messrs Tandy and Russell outlined the work contemplated. On 16th July, 1928, Sir Arnold Theiler gave an address on "Problems of Phosphorus Deficiency of Stock". On 4th March, 1929, Professor Johannes Schmidt, D Sc, Ph D, Director of the Carlsberg Laboratory, Copenhagen, and leader of the Danish Oceanographical Expedition, delivered a lecture on the life history of the eel.

The Council wishes to acknowledge generous subsidies amounting to £147 from the Queensland Government towards the cost of printing the Proceedings of the Society. Appreciative acknowledgment is also made to the University of Queensland for housing the library and providing accommodation for meetings.

The membership roll consists of 4 corresponding members, 6 life members, and 176 ordinary members. During the year there were five resignations, and nine new members were elected. The deaths of Dr J V Danes, of the Czech University, Prague, a corresponding member, and of Mr W R Colledge, a past president of the Society and a frequent contributor to the proceedings, are reported with regret. Mr Rowland Illidge, a former honorary librarian of the Society, has been lost from the ranks of Queensland biologists by death.

There were nine meetings of the Council. The attendance was as follows — E W Bick 8, W H Bryan 7, J V Duhig 3, E. J. Goddard 2, R W Hawken 4, D A Herbert 9, T G H Jones 4, H A Longman 4, E O Marks 8, T Parnell 7, H C Richards 6, C T White 7, Dr J P. Lowson was unable to attend as the hour of the meetings was unsuitable.

T PARNELL, President.

D A HERBERT, Hon Secretary

THE ROYAL SOCIETY OF QUEENSLAND

Dr. STATEMENT OF RECEIPTS AND EXPENDITURE FOR YEAR ENDING 31st DECEMBER, 1928

RECEIPTS		EXPENDITURE		ABSTRACT OF PROCEEDINGS.	
	£ s d			£ s d	
Bank Balance, 31st December, 1927	36 0 6	Government Printer—		7 7 3	
Subscriptions	147 10 6	Stationery Account		294 10 0	
Government Subsidy on cost of Printing	147 0 0	Printing Account, Volume and Abstracts		11 0 0	
Sale of Reprints	15 10 0	Hon Secretary (Postages)		9 9 3	
Sale of Bookcase	10 0 0	Library Furniture		15 0 0	
Exchanges	7 6	Library Shelving		13 0	
Cheque B976134, not presented at 31st December 1928	15 0 0	State Government Insurance		5 6 0	
		Advertising Letters		1 10 0	
		Lanterns		8 10	
		Exchanges		10 0	
		Cheque Book		10 0	
		Bank Charges		25 4 2	
		Balance in Q N Bank, 31st December, 1928			
	£371 8 6			£371 8 6	

H J PRIESTLEY, Hon Auditor

E W BICK, Hon Treasurer

ABSTRACT OF PROCEEDINGS, 25TH MARCH, 1928

The Annual Meeting of the Society was held in the Geology Lecture Theatre of the University at 8 p.m. on Monday, 25th March, 1928. The President, Professor T. Parnell, occupied the chair. Apologies for absence were received from Professors E. J. Goddard and H. C. Richards and from Mr T. Rimmer. The minutes of the previous meeting were read and confirmed. The annual report and balance sheet were adopted.

The following officers were elected for 1929 —

President Professor J. P. Lowson, M.A., M.D.

Vice Presidents Professor T. Parnell, M.A. (*ex officio*) and Mr J. B. Henderson, F.I.C.

Hon. Secretary Mr F. A. Perkins, B.Sc. Agr.

Hon. Librarian Mr W. D. Francis

Hon. Treasurer Mr E. W. Bick

Hon. Editors Mr H. A. Longman, F.L.S., C.M.Z.S., and Dr W. H. Bryan, M.C.

Hon. Auditor Professor H. J. Priestley, M.A.

Members of Council Dr C. D. Gillies, M.B., B.S., M.Sc., Professor R. W. Hawken, B.A., M.E., M.Inst.C.E., Mr D. A. Herbert, M.Sc., Dr T. G. H. Jones, A.A.C.I., Mr R. Veitch, B.Sc.

Mr W. G. Wells was nominated for ordinary membership and Mr C. Schindler for associate membership.

Professor J. P. Lowson was inducted to the position of President for 1929. Professor T. Parnell delivered his Presidential Address entitled "Modern Developments of Physical Science." On the motion of Professor R. W. Hawken, seconded by Mr J. B. Henderson, a vote of thanks was accorded the retiring president for his address. A paper by Dr T. G. H. Jones and Mr F. B. Smith, B.Sc., on "The Volatile Oil of Queensland Sandalwood" was laid on the table. Mr H. A. Longman expressed the Society's appreciation of the presence of His Excellency the Governor.

ABSTRACT OF PROCEEDINGS, 29TH APRIL, 1929

The Ordinary Monthly Meeting was held in the Geology Lecture Theatre on Monday, 29th April, 1929, at 8 p.m.

The President, Professor J. P. Lowson, in the chair, and about thirty members present. Apologies for absence were received from Messrs Francis and Veitch.

The minutes of the previous meeting were read and confirmed. Mr W. G. Wells (ordinary) and Mr C. Schindler (associate) were unanimously elected members of the Society.

Miss D. Hill, B.Sc., Miss N. Holdsworth, and Mr L. F. Mandelson, B.Sc., Agr., were nominated for ordinary membership.

Dr F. W. Whitehouse exhibited the following fossils — (1) Flowers

of *Williamsona*, associated with the fronds of *Ptilophyllum*, from the Jurassic deposits (Walloon series) of Bymount, north of Roma, (2) Specimens of a new species of *Calceola* from the Devonian beds of Ukalunda, North Queensland (collected by Mr J H Reid, (3) *Stringocephalus* sp from the Devonian limestone of Calcum, North Queensland *Calceola* and *Stringocephalus*, index genera of the Estolian and Givetian, respectively, of Europe are thus recorded for the first time from Queensland

Dr W H Bryan exhibited some rather rare rocks from Milford Sound, New Zealand, which had been presented to the University of Queensland by Dr P Marshall. The rocks comprised Harzburgite (Saxonite), Dunite, Enstatite, and a perfectly white olivine carbonatic rock. Specimens of Dunite and Harzburgite from the type areas were also shown for purposes of comparison.

Mr D A Herbert exhibited (a) *Hydrodictyon reticulatus* from Lake Manchester, (b) *Craterium confusum*, a myxomycete from Woolloowin, (c) *Ustilago violacea*, a smut fungus attacking *Carex pseudocyperus* from Kuraby and (d) a French bean showing polyembryony. The first three are new records for the State.

Mr A K Denmead exhibited a small fossil identified by Mr R A Keeble as belonging to the family *Diplograptidae*, from Brisbane schists (Middle of Bunya series), of Tweed Heads. The age was considered to be top of the Ordovician or lowest Silurian.

Mr J E Young exhibited a piece of coral containing a crab gall produced by the female of *Haplocarcinum marsupialis*.

Mr C T White exhibited specimens of (1) *Ficus Baileyana* Domin from trees growing in Botanic Gardens, Brisbane. This tree was originally named by F M Bailey as *F. macrophylla* Desf var *pubescens*, and is related to *F. macrophylla* Desf on the one hand and to *F. rubiginosa* Desf on the other, but is distinct from either and seems worthy of specific rank. It is common in cultivation, and specimens are to be found growing in the Botanic Gardens at Brisbane, Sydney, and Adelaide. Both Bailey and Domin record it for the rain forests of South Queensland, but this, Mr White thinks, is pure guesswork, as though common in cultivation the plant has not as yet been found in a wild state. Specimens of *F. macrophylla* Desf and *F. rubiginosa* Desf were also shown for purposes of comparison, (2) Specimens of a small tree belonging to *Eucalyptus*, or allied genus growing on sandy hills at Plunkett. The exact botanical position of this tree is a matter of doubt until flowers have been collected.

Mr J B Henderson exhibited an Analytic Quartz Lamp. This is a mercury vapour lamp so fitted with two Wood's filters that ultra-violet rays are projected horizontally and vertically. The vertical rays fall inside movable black curtains, so that specimens may be examined for fluorescence in daylight. The effect of the ultra-violet rays was shown on various drugs and chemicals, also on papers, minerals, and precious stones.

Mr C Morton exhibited specimens of Rutile (red) surrounded by a zone of Ilmenite (black) in rounded as well as roughly crystalline forms up to 2 inches in maximum dimension. They were obtained from shallow alluvial deposits near the Burrandowan road about 22 miles west of Kingaroy. The country rock is gneissic granite, in which similar specimens were found to occur as isolated individuals.

Dr E Marks exhibited two rocks, a trachyte and a tuffaceous conglomerate found at Upper Brookfield.

Dr Whitehouse, Dr Bryan, Dr Marks, and Messrs White, Jackson, Massey, Denmead, and Jones commented on the exhibits.

ABSTRACT OF PROCEEDINGS, 27TH MAY, 1929

The Ordinary Monthly Meeting was held in the Geology Lecture Theatre of the University on Monday, 27th May, 1929, at 8 p.m. The President, Dr J. P. Lowson, in the chair. Apologies were received from Messrs Herbert, Perkins, and White. The minutes of the previous meeting were read and confirmed. Miss D. Hill, B.Sc., Miss N. M. Holdsworth, and Mr L. F. Mandelson, B.Sc., Agr., were unanimously elected to ordinary membership.

Dr E. O. Marks exhibited water-worn pebbles of trachyte found embedded in sandstone near the summit of Candle Mountain. Dr E. O. Marks exhibited on behalf of Mr H. A. Longman aboriginal skulls and showed how they differed in the zygomatic arch from those of whites.

Mr W. D. Francis, on behalf of Mr C. T. White, read a résumé of a paper of Dr C. C. J. van Steenis, entitled "A Revision of the Queensland Bignoniaceæ." Nearly all the Australian members of the family are represented in Queensland. Dr Steenis makes some changes in nomenclature in agreement with the international rules of nomenclature. He adopts the name *Pandorea* for the Australian species previously placed under *Tecoma*. The Queensland species number twelve, and are placed in twelve genera.

Dr R. Hamlyn-Harris read a paper entitled, "The Relative Value of Larval Destructois and the Part they Play in Mosquito Control in Queensland." Successful experiments with various members of the Characæ rule these out as possible larvicides. (A jar containing *Nitella phauloteles* (id. by J. Groves), was exhibited to the meeting. *Culex fatigans* in all stages of development, from the eggs to the maturing pupæ, showed perfectly normal conditions, brought about by the larvae being fed every second day or so on an animal diet, piscidin.)

Queensland possesses several mosquitoes cannibalistic in the larval stage, known to be most voracious, two of these, viz., *Lutza halifaxi* and *Megarhinus speciosus*, are perfectly harmless to human beings, and it is thought that some use might be made of them economically.

There seems to be some diversity of opinion with regard to Tadpoles,

and, being for the greater part vegetable feeders, no direct evidence is offered to justify the idea that they devour mosquito larvæ, though investigators in other parts of the world have found certain species useful

Predatory aquatic Hemiptera may be broadly classed as larval destructors and include effective members of the Gerroidea, Notonectoidea, and Corixoida. Of even greater value are aquatic Coleoptera (both adults and larvæ) of the super-families Caraboidea, Gymanoidea, Hydrophilodæ (in the larval stages only), and Australian Odonata

In addition to these larval destructors others include species of Hydræ, Hymenoptera, Diptera, Molluscs, and other enemies

Queensland is particularly fortunate in possessing a large number of larvivorous fish capable of doing good work in fresh, brackish and salt water. Among these the species most highly recommended are *Craterocephalus fluviatilis* and *Melanotacna nigra* for fresh water, and *Pseudomugil signifer* for brackish and salt water. A distinction is drawn between larvivorous fish as surface-feeders and larvæ-eating as bottom feeders of which the Gudgeons are the main representatives. The mortality among fish is due to drought conditions and various enemies, but in spite of this they are nevertheless able to maintain themselves to our advantage and to restock natural waters after periods of flood. Several fish, hitherto overlooked, are here recorded as larval destructors for the first time

The paper was discussed by Mr F. Bennett, Dr L. O. Marks and Mr Inigo Jones

ABSTRACT OF PROCEEDINGS, 24TH JUNE, 1929

The Ordinary Monthly Meeting was held in the Geology Lecture Theatre of the University on Monday, 24th June, at 8 p.m. The President, Dr J. P. Lowson, in the chair. An apology was received from Mr Herbert. The minutes of the previous meeting were read and confirmed. Dr Ellis Murphy was proposed for ordinary membership.

Mr G. H. Hardy read extracts from his paper, entitled "Revisional Notes on the Tribe Brachyrhopalini, with Remarks on the Habits of and Mimicry amongst Robberflies." He discussed the generic alliances of species included in the tribe, and incorporated keys to the five genera and fifteen species constituting the group. Observations on the habits of robberflies indicated the possibility that mimicry amongst robberflies may occur, and evidence may be obtained from the fact that certain species regarded as being wasp mimics have habits differing from those of their nearest allies. Particular attention was drawn to *Erythropogon limbipennis* (Macquart), which does not seem to be predaceous.

Dr T. G. H. Jones read extracts from his paper on "A Contribution

to the Chemistry of the Only Exudate of the Wood of *Pentaspodon motleyi* (Papua) "

The exudation from the wood of *Pentaspodon motleyi* on examination has been found to consist essentially of apparently homogeneous acid material, for which the name pentaspodonic acid is proposed. Conclusions as to the constitution of this acid are drawn from various experiments recorded, and it is considered that the acid has a molecular composition $C_{22}H_{24}O_8$. Two unsaturated linkages are present in a long side chain attached to a benzene nucleus. The acid, which is monobasic, also contains one phenolic group.

The Secretary read extracts from the paper by John Legg, D V Sc., and J L Foran entitled "Some Experiments on Tick-infested Cattle with Arsenical Dipping Fluids". The following took part in the discussion which ensued: Dr Jones, and Messrs Pound, Jones, Perkins, Henderson, and Schindler.

Mr H A Longman exhibited a small slab of fossiliferous limestone which had been found by Miss Marion Rowland amongst rocks considerably above high-water mark on Magnetic Island, North Queensland. This slab contained, amongst other remains, several specimens of *Barnacles*, apparently *Coronula* sp., present-day species of which are found parasitical on whales. Evidently this slab had been detached from its original stratum, and if this could be traced it would be of considerable interest.

Mr Longman also exhibited specimens of the lower jaws of *Maciopus anak* and *M. tacchus* from the Darling Downs, which he considered were distinct species as indicated by Owen. He could not agree with De Vis in "lumping" both of these under *Maciopus anak*.

ABSTRACT OF PROCEEDINGS, 29TH JULY, 1929

The Ordinary Monthly Meeting was held in the Geology Lecture Theatre of the University on Monday, 29th July, at 8 p.m. The President, Professor J P Lowson, in the chair. Apologies were received from Professor Goddard, Dr Herbert, and Messrs Mandelson and Veitch. The minutes of the previous meeting were read and confirmed. Dr Ellis Murphy was unanimously elected a member of the Society.

The Secretary read extracts from a paper by Dr John Legg entitled "Some Observations on the Life History of the Cattle Tick."

Dr W H Bryan and Dr F W Whitehouse read a paper entitled "A Record of Devonian Rhyolites in Queensland." The paper reviewed the evidence of the occurrence of Devonian Rhyolites at Kangaroo Hill and Mount Coolon, and placed on record several other rhyolitic series (some of proved Devonian age and others apparently belonging to that period), discovered by one or other of the authors within the last few years, from the following localities—Herberton, Mount Etna, Tungamah, Mount Morgan, Raglan, Gore.

Dr. W H. Bryan exhibited (1) An amethyst-coloured specimen of halite (rock salt) obtained by the Chief Government Geologist (Mr B. Dunstan) from the Kaiserrode Mine, Borken, Germany, (2) A specimen of decomposed but unweathered granite from the Ashgrove Quarry, Brisbane, containing purple crystals of fluorite associated with quartz and zeolites This marked the first record of fluorite from the Enoggera Granite

ABSTRACT OF PROCEEDINGS, 26TH AUGUST, 1929

The Ordinary Monthly Meeting was held in the Geology Lecture Theatre of the University on Monday, 26th August, at 8 p.m. Mr F. Bennett, B.Sc., in the chair and seven members present. The minutes of the previous meeting were read and confirmed. Mr H. J. G. Hines, B.Sc., was proposed for ordinary membership by Mr Perkins, seconded by Dr Herbert.

Mr C. T. White, F.L.S., read a paper by himself and Mr Francis, entitled "Contribution to the Queensland Flora, No. 4." Two new species—*Labichea Brassii* from North Queensland and *Albizia xanthoxylon* from the Alberton district—were described as new, and several plants were recorded from Queensland for the first time.

Dr D. A. Herbert read a paper, entitled "Changes in Osmotic Pressure in Relation to Movement of *Mimosa Pudica*."

Dr. Herbert exhibited (1) *Empusa muscae*, a fungus causing fly cholera, and (2) *Penicillium expansum*, a mould from a decaying custard apple, also found on the apple.

Mr C. Schindler exhibited a rust fungus, *Phragmidium longissimum*, on *Rubus parvifolius*, from Mount Crosby.

ABSTRACT OF PROCEEDINGS, 30TH SEPTEMBER, 1929

The Ordinary Monthly Meeting was held in the Geology Theatre on Monday, 30th September, 1929, at 8 p.m.

The President, Professor J. P. Lawson, M.A., M.D., in the chair. Mr H. J. G. Hines, B.Sc., was elected to ordinary membership.

Professor E. J. Goddard, B.A., D.Sc., delivered a lecture entitled "Science and Agriculture in Java." A vote of thanks was carried on the motion of Dr W. H. Bryan, M.C., seconded by the President.

ABSTRACT OF PROCEEDINGS, 28TH OCTOBER, 1929

The Ordinary Monthly Meeting was held in the Geology Lecture Theatre of the University on Monday, 28th October, at 8 p.m. Professor J. P. Lawson, M.D., in the chair, and about thirty members present. The minutes of the previous meeting were read and confirmed.

Miss D. Hill, B.Sc., read a paper entitled "The Stratigraphical Relationship of the Shales about Esk." The work indicated that the Esk Shales of the Ipswich coal measures represent closely related phases in a shallow fresh water basin, with but a slight chronological difference. For in effect the Basal Conglomerate of the Ipswich series changes laterally into the highest of the Esk series—the Esk shales. Both these are conformably underlain by a volcanic stage. The Ipswich coal measure shales thin out rapidly northward and are missing from the basin north of Bellevue, where the overlying Bundamba comes to rest without apparent unconformity on the Esk Shales. The paper was discussed by Professor Richards, Drs. Bryan, Marks, and Whitehouse, and Messrs. Jones, Reid, and Tommerup.

Mr. Inigo Jones exhibited slides of the 1893 flood of the Brisbane River and maps of the area affected.

Dr. F. W. Whitehouse exhibited Bryozoa from the Lower Carboniferous limestones of Riverleigh, near Mundubbera. These included two species of *Archimedes* (genus new to Australia) and one of *Eractinopora* (genus new to E. Australia). The limestone with *Archimedes* contains the *Amygdalophyllum* coral fauna. The *Eractinopora* limestone is probably somewhat higher in the section.

ABSTRACT OF PROCEEDINGS, 25TH NOVEMBER, 1929

The Ordinary Monthly Meeting was held in the Geology Lecture Theatre of the University on Monday, 25th November, at 8 p.m.

Professor J. P. Lawson, M.D., in the chair, and about thirty members present.

The minutes of the previous meeting were read and confirmed.

Messrs. D. O. Atherton and H. K. Lewcock, M.Sc., were proposed for ordinary membership by Mr. Perkins, seconded by Dr. D. A. Herbert.

Dr. Herbert read a paper entitled "*Cyttaria septentrionalis*," a new species of fungus attacking the beech (*Nothofagus Moorii*) in Queensland and New South Wales. This fungus is one of the stromatic Pezizales and the genus is found in South America, New Zealand and Tasmania, on various species of *Nothofagus*. The new species extends the range of the genus to Queensland, and makes the range practically that of the host genus. The specimens were collected by Mr. C. T. White (Government Botanist) and by the author at different times on Mount Hobbes in National Park, on the New South Wales border. It is limited to a few acres of beeches on the mountain top, and seems to be confined to the portion of the mountain commonly enveloped in clouds. It is edible, as are other species of the genus.

A discussion of the paper, in which Drs. Bryan, Marks, Whitehouse, and Messrs. Bennett, Jones, and Perkins took part, developed on the bearing of this and other evidence on the Wegener hypotheses.

Publications have been received from the following Institutions,
Societies, etc., and are hereby gratefully acknowledged

AFRICA

ALGERIA —

Société de Géographie et d'Archéologie
d'Oran Oran

UNION OF SOUTH AFRICA —

Durban Museum Natal

South African Museum Capetown, Cape
Province

Historical Museum Pretoria

Geological Society of South Africa,
Johannesburg

AMERICA

ARGENTINA —

Museo de la Plata Universidad Nacional
de la Plata

BRAZIL —

Instituto Oswaldo Cruz Rio de Janeiro

Ministerio de Agricultura, Industria y
Comercio Rio de Janeiro

CANADA —

Department of Agriculture, Ottawa

Department of Mines Ottawa

Nova Scotia Institute of Science Halifax,
Nova Scotia

Royal Society of Canada Ottawa

Royal Astronomical Society of Canada
Toronto

Royal Canadian Institute, Toronto

UNITED STATES OF AMERICA —

Bingham Oceanographic Institute, San
Diego

Florida Geographical Society

Carnegie Institution, Washington

Library of Congress Washington

National Academy of Sciences Washington

National Research Council, Washington

Smithsonian Institution, Washington

United States Department of Agriculture
Washington

United States Department of Commerce
(Bureau of Standards) Washington

United States Department of the Interior
(United States Geological Survey),
Washington

United States National Museum, Washing-
ton

United States Treasury (Public Health
Service)

Lawde Observatory, Arizona

Scripps Institute of Oceanography, La
Jolla U.S.A.

University of California Berkeley Cali-
fornia

John Hopkins University (Institute of Bio-
logical Research) Baltimore

American Academy of Arts and Sciences,
Boston

Boston Society of Natural History Boston

Buffalo Society of Natural Science Buffalo

John Crerar Library Chicago

Field Museum of Natural History Chicago

Floyd Library Cincinnati

Ohio Academy of Science Columbus

Ohio State University Columbus

Bishop Puaiah Bishop Museum, Honolulu

Natural History Survey State of Illinois

Indiana Academy of Science Indianapolis

Cornell University Ithaca, N.Y.

Cornell University Agricultural Experi-
mental Station

Arnold Arboretum Jamaica Plain Massa-
chusetts

Wisconsin Academy of Arts, Science, and
Letters Madison

Michigan Academy of Arts, Science and
Letters Michigan

University of Michigan Michigan

Minnesota Geological Survey, Minneapolis

University of Minnesota Minneapolis

New York Academy of Sciences New
York

American Geographical Society New York

American Museum of Natural History
New York

Bingham Oceanographic Collection, New
York

New York Zoological Society New York

Oberlin College, Ohio

Academy of Natural Sciences Philadelphia

American Philosophical Society Phila-
delphia

Portland Society of Natural History

Rochester Academy of Sciences Rochester

San Diego Society of Natural History San
Diego

California Academy of Sciences San
Francisco

Puget Sound Biological Station, Seattle

Missouri Botanic Garden St. Louis

University of Illinois, Urbana

University of Kansas, Lawrence, Kansas

MEXICO —

Instituto Geológico de México, Mexico.

MEXICO—continued

Sociedad Cientifica, "Antonio Alzate,"
Mexico
Observatorio Meteorologico Central, Tacas-
baya, D F, Mexico
Secretario de Agricultura y fomento,
San Jacinto D F, Mexico

PERU

Sociedad Geologica, del Peru, Apartado
de Correos No 1669, Lima, Peru

ASIA**Ceylon—**

Colombo Museum, Colombo

INDIA—

Agricultural Research Institute, Pusa
Government of India—
Department of Agriculture
Geological Survey
Superintendent, Government Printing
Punjab University
Indian Academy of Science

JAPAN—

Imperial University, Kyoto
Imperial University, Tokyo
National Research Council of Japan,
Kuno Tokyo

JAVA

Koninklijke Naturkundige, Batavia
Departement van Landbouw, Buitenzorg

PHILIPPINE ISLANDS—

Bureau of Science Manila
College of Agriculture University of the
Philippines Manila

AUSTRALIA AND NEW ZEALAND**COMMONWEALTH—**

Australian Commonwealth Engineering
Standards Association, 16 College
Street Sydney
Commonwealth Department of Health,
Spring Street Melbourne
Council for Scientific and Industrial Re-
search 314 Albert Street East
Melbourne

QUEENSLAND—

Department of Agriculture Brisbane
Department of Mines, Brisbane
Queensland Geological Survey, Brisbane
Queensland Museum, Brisbane
Queensland Naturalists' Club, Brisbane
Royal (Geographical) Society of Australasia
(Queensland) Turbot Street, Brisbane
State Statistician Brisbane

NEW SOUTH WALES—

Australasian Association for the Advance-
ment of Science, Royal Society's Hall,
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Proceedings of the Royal Society of Queensland.

Presidential Address.

By PROFESSOR J P LOWSON, M A, M D

(Delivered before the Royal Society of Queensland, 31st March, 1930)

The report which has been submitted to you shows that the work of the Royal Society during the past year has been both considerable in quantity and varied in interest. The fourteen papers published cover a wide field, including work done in physics, chemistry, geology, botany, and zoology both theoretical and applied. The recently issued volume 18, I think, a worthy record of the Society's work.

There is one matter not included in the report which I should like to mention. I refer to the very valuable and now completed work which has been done in the arrangement and cataloguing of the Society's library. I think the thanks of the Society are due to the librarian, Mr Francis, and also to Mr Hardy, for this work.

I should also like to add my thanks to those of the Society to Dr Duhig for his generous donation to the library.

RECENT PSYCHOLOGY

Following the example of my predecessor, Professor Parnell, who gave us last year so excellent a résumé of recent progress in physical science, I wish to put before you in this address a few of the ideas which have become centres of interest in psychology in the course of the last twenty years. This is not altogether an easy task. Psychology is the youngest of the sciences, and has but just entered on what promises to be a period of rapid and successful growth. There is at present, as always at such times, much divergence of opinion as to what must be regarded as established matter of fact, what should be held in suspense as matter of possibility or probability only, and what should be rejected in the meantime as mere speculation. Some results of psychoanalytical research, for example, which are of great interest and importance and cannot be omitted, are still regarded as matter of controversy by a number of psychologists. On this head I can only say that while, on the one hand, my account will contain no specially original features—that is, no doctrines peculiar to myself—on the other hand, I shall

make no statement with which my own experience does not lead me to agree. I am aware also that part of what I have to say is not likely to make pleasant hearing. It is scarcely possible to discuss developmental psychology without running unwitting offence to some one. But we have to recognise, in psychology as in biology generally, that Nature is independent of our human prepossessions, and that, if we wish to deal with her successfully, we must take her in the first instance as she is.

There are two topics in psychology to which I wish specially to direct your attention. The first is the fact of the continuous persistence of the past into the present in our mental life, the fact that a man's mental present, his actual present ways of thinking, feeling, and acting, are not only based upon but bound up with and to a very large extent determined by his whole mental past, by all that he has thought, felt, and done, and by all that has been done to him from birth onwards. The second topic to which I wish to direct your attention is the manner in which certain peculiarities of human sexual development interact with this persistence of the past, so as to produce important practical results.

When we consider our conscious experience, as it immediately presents itself to us, perhaps the most striking feature about it is its kaleidoscopic change. Change seems to be the condition of its very existence, for without change attention and consciousness itself quickly lapse. Moment succeeds moment, event succeeds event, thought succeeds thought, and feeling follows feeling. Our mental lives have been described as consisting of an innumerable succession of states of consciousness, as they have been called, no one of which is ever exactly like those that precede or those that follow it, no one of which is ever exactly repeated. This is so obvious that the term "stream of consciousness" has long been current in psychological language to express what seems at first sight an ever-changing flow.

When the matter is considered more closely, however, we come to see that the word "stream" with its suggestion of a procession, each feature of which appears for a moment only to vanish and leave no trace, is more misleading than helpful as a description of our mental life. A close study of any particular conscious stream reveals always a very large number of constantly repeated features, ways of thinking, for instance, methods of action, peculiarities of feeling, traits of character, and the like. Of much that goes on in consciousness the old French tag turns out to be an exact description: "*Plus cela change, plus c'est la même chose*." The content may change but the form and purport remain the same. In order to explain these constant features we are obliged to assume the existence of some kind of unconscious organisation underlying the stream of conscious change, persisting and developing beneath it, and determining in large measure the forms which its activity takes. We may identify this organisation with brain organisation, if we choose, neglecting the fact that for the moment brain physiology can give no account of it, or we may stick to observed fact,

and leave that question open for the present. In any case we should have to assume the existence of such a developing organisation underlying consciousness if we had never seen a brain at all. In the end we find it best to abandon the metaphor of a stream altogether, and introduce the concept of an organic mental structure which persists and grows in interaction with the external world, somewhat as the seedling persists and grows into the fully developed tree. We come to regard consciousness itself as the expression of activity in this organisation in interaction with the outer world from moment to moment. We note that consciousness is mainly confined to those mental activities which are in direct relation with the outer world. On the one hand we explain changes in consciousness in terms of the flux of external events and the varying needs of the mental organism, on the other hand, we explain the perpetual repetition which characterises conscious activity, the perpetual reapplication of the same ways of perceiving, thinking, feeling, and acting to differing material, by means of the persistence of the mental organisation itself and the continuity of its development. It is this latter side of the situation which I propose to discuss.

That some such persistent organisation must exist is easy to show. Everyone knows that even from the point of view of consciousness the past does not disappear completely. We know that we can reproduce in conscious memory a great deal which we have thought and felt and done in the past. This fact obviously implies that our experiences have left some sort of traces behind them, which can in some degree be re-excited so that the past lives again. It implies, in short, the existence of a more or less permanent structure of memory traces which has been woven out of our past experience, and makes possible the repetition of the past in the present.

But the persistence of the past and its repetition in the present in mental life are by no means confined to conscious memory. On the contrary, while conscious memory with its definite time reference is a highly specialised mental function, the repetition of the past in the present is a constant feature of mental organisation and mental function in general.

This fact is most obvious in relation to our intellectual development and the development of our knowledge generally. In that connection it is well recognised in introspective and experimental psychology. The psychology of perception, for instance, is one long exemplification of this fact, since the possibility of the simplest as well as the most complicated act of perception depends essentially upon a condensation of the past in the present through which the present acquires meaning for us in the light of the past. This condensation has nothing to do with conscious memory. It is immediate and irreflective. In most cases we have to consider its results to become aware that it occurs. As, for example, we glance round the room in which we are, it is by no means the room as it immediately affects our senses which we see. It is on

the contrary a beautifully organised, or, as we say, integrated condensation of a vast amount of past experience of light and colour, touch and pressure, space, movement, and every other experienced possibility of sensation in such a situation as the present one. The room as we see it is in the main an imaginative product, but it certainly does not look like that to us. That is because, as we look at it, we actually see the past in the present. The pattern of stimulation which affects our senses fuses indistinguishably with perceptual patterns which come into action from within. This is of course more obvious, though not a whit more true, when the objects of which we are aware are removed from influence on our senses. No one of us in this room but is aware, without so much as once deliberately thinking of it (preconsciously aware, as we say), of the building in which he is, of the park outside, of George street, Brisbane, Australia, the whole planet, and the universe of space, so far as they are known to him as wholes. The world picture, in short, which every man carries in his head, is clearly not an affair of immediate sensation but of the imagination which the senses have trained. It sums his past experience in that respect from infancy upwards. It is the past experienced in the present.

I stress these facts in the first instance because it is not adequately recognised what a remarkable magic lantern the human mind is. The screen of consciousness on which our external experience itself appears is lit up from within as well as from without. The pictures which appear on it are thrown mainly from within, usually in response, it is true, to what is thrown from without. Normally, however, what is thrown from within in response to what is thrown from without harmonises so beautifully that we are incapable of distinguishing the inner from the outer light, and can only distinguish by inference between the present and the past components of the total picture. But in nervous breakdown, for example, where the two pictures usually clash in some respect or other, still more in insanity, where they clash irreconcilably and the inner pictures begin to get the better of the outer, the true nature of the normal situation itself begins to become apparent. Let me continue for a moment with the same image, crude though I admit it to be. It is somewhat as though what we perceive or what we think in consciousness were a consequence of a play of light streaming towards an exterior screen through a vast succession of lantern slides. It is as if from an integration of all the slides through which the light travels in response to what is given from without through the senses that the ultimate pictures result. We have also reason to think that, while these pictures may go on enriching and complicating as fresh experience comes in, yet within them something of the simpler outlines of the earlier pictures of the same series will always tend to persist. The past is never completely obliterated and the present perpetually repeats the past.

If what I have said will suffice for perception and thought, it must suffice for action also. What is true of perception and thought is naturally true of action, of what we have learned to do as of what we

have learned to perceive or think. The same considerations apply in the one case as in the other and the past persists and repeats itself in action as it does in thought.

But at this point a question arises. If the image just used is not wholly wrong, if perception, thought, and action are partly the consequences of an energy streaming from within, it seems natural that this energy should flow mainly into paths already organised out of past experience, but what is the nature of the energy itself? To this question we can reply in the first instance, that whatever the intimate nature of this energy may be, observation shows that in consciousness it is correlated with, or represented by, what we call interest, that so far as mental life is concerned interest and energy are equivalent terms, and that interest in turn stands in the closest relations with the life of feeling and desire as distinguished—so far as it can be—from the life of thought and deliberate action.

An important advance in recent psychology has been the recognition of the dominant part played by feeling and desire in every mental activity without exception. Psychology, deriving, as it did, from philosophy, was for a long time chiefly occupied with the intellectual processes, which are in any case the most obvious feature of our mental life. As soon, however, as the science came into contact with problems of actual life, medical problems particularly, as it happened, it became evident that it is from feeling and desire that the energy derives on which thought and action are run, and the study of feeling and desire began to assume something like its rightful position in psychology as a whole. We now recognise that the capacity of any idea to exert any influence whatever on thought or action depends on the energy which it is capable of letting loose in the shape of feeling and desire, and further, that the kind of thought or action which follows will depend on the nature of the feelings or desires which have been excited, since it is their satisfaction which thought and action will aim at. We find that we cannot answer the question of why a man thinks and acts as he does until we have investigated how he feels about what he thinks and does, and this in turn resolves itself into a question of what the desires are which furnish the motive power to his thought and action, and how they came into being.

This last question brings me back to my principal theme. While the persistence of the past and its repetition in the present are easily recognised in relation to our intellectual and practical activities, they are not so readily recognised in relation to our feelings and desires, that is, in relation to our emotional life and its development. A further step forward in psychology has been the recognition that our emotional present develops out of and repeats our emotional past just as present intellectual and practical capacities develop out of and repeat past ones. Just as little in the emotional as in the intellectual sphere do new feelings or new ways of feeling come into being out of nothing and without relation to the past.

This principle, once recognised, again appears natural enough. Faced with a momentary situation how are we to react emotionally if not as we have already reacted to similar situations in the past? No doubt if we can discriminate consciously in what appear to us to be essential respects between the present and past situations of the same kind our emotional response will differ accordingly, but this is, actually, far from easy in very many cases. In the first place, we respond emotionally at once before we have time to think—more correctly, we have to respond emotionally before we can think—and, in the second place, in nine cases out of ten we are unable to tell to what similarities our immediate emotional response is due. A high degree of emotional discrimination is, actually, a rare quality among human beings. This fact is most easily recognised, perhaps, in reference to our social responses. When, for example, we meet a new acquaintance, we like him, or dislike him, or experience a mixture of these feelings, as a rule immediately. But, in the first place, it is the exception for us to be able to say what exactly are the traits which have called out our immediate liking or the reverse, in the second place, suppose we can do so, it is very difficult as a rule to identify the previous experiences which have determined our feeling for these traits, and, finally, the first occasion on which our response to them was determined, which is actually the most important of all, is usually quite beyond the reach of conscious recollection. In most cases, in fact, we do not reflect much on the matter at all. We accept and follow our likes and dislikes as something natural to ourselves and not in need of explanation. Nevertheless they are invariably determined by the past, which they repeat.

This principle is of very great importance in our emotional life, and perhaps I can best make it clear by means of a simple example. Two of the fundamental social feelings are liking and dislike, love and hate. These are emotional capacities of which we all possess a share, but we must all have met persons who show an unusually marked disposition towards hate, either open or veiled in its expression, and been struck at times by the irrationality of their feeling since it plainly bears little or no relation to the real qualities of its objects. We may be tempted to explain this irrationality by reference to the inborn disposition of the persons concerned, and to suppose that hatred is natural to them. But investigation of such cases shows as a rule that their disposition to hatred is not inborn but acquired, that its irrationality in the present results from the fact that its real determinants are in the past, and that at its commencement it was justified. I select a simple illustration of this sort.

Consider the emotional development of a boy who has been led from infancy to hate his parents. A certain amount of such hatred (at least for one parent) is normal in infancy, as I shall later point out, but its persistence in force implies usually qualities in the parents—unkindness, injustice, oppression, and the like—which have themselves called it out. Now a boy's parents are in infancy the concrete embodiments of superior

strength and authority, it is from their images that these ideas are abstracted first of all. This is, of course, specially true of a boy's father. We have, then, an association of these ideas with the images of the parents, an association formed in the earliest years and backed by strong feeling. Such a primary association, we find, tends to persist unconsciously throughout the whole life. We find that the boy's hatred will tend, of itself and without his conscious co-operation, to flow out subsequently to all other persons perceived as superior in strength or authority, and hence perceived at the outset, usually unconsciously, as reincarnations of his parents. He will grow up with a disposition towards hate and instinctive hostility, tending to involve all such persons, and perhaps with a morbid and misleading sensitiveness to the slightest suggestion or fancied suggestion of injustice or oppression. It is obvious that he is not likely to get on well with teachers, or employers, or authority in any form, and, since dislike and hostility on our part beget like feelings towards us in those for whom we feel them, the response he calls out is only too likely to justify his feeling from his point of view. Thus, from the point of view of its objects, his hate will be like a tree, the later hatreds branching out from the original hate, to which in most instances they will owe the greater part of their strength. Again, the better stuff he is made of, the more energy and spirit he has, the more plainly will his hostility appear, and he may get a reputation as a contumacious subject or a socially impossible person which may do him great harm.

This is a much simplified instance but we may safely generalise from it. There is no reasonable doubt that all sorts of disadvantageous peculiarities of character and feeling are acquired in this manner, as well as all sorts of advantageous qualities. We get the impression from our experience that our unconscious emotional and impulsive development is somewhat like a tree which branches out as we grow from infancy into manhood. In the tree the final form may be very different from that of the seedling from which it sprang, nevertheless every branch has sprung from a pre-existent branch, that from another, and so back to the original main stems, and every leaf which it turns to the air and light still draws nourishment from fibres that run from origin to origin down through the stem into the roots below. Within this arrangement the whole history of the tree is contained. So the developed mind of a man may be very different from that of the child he once was, but the channels through which there come unconsciously into his conscious life the energies which vivify it go back and back within the unconscious organisation of the mind, concentrating and simplifying as they go, till they reach the main sources of emotion and desire in his forgotten childhood. Within this emotional organisation his whole emotional history is contained.

The social importance of what I have said is evident. The facts of emotional development open up the possibility of a form of culture hitherto neglected. The cultivation of the intellect and the cultivation of practical capacities are ideas with which we are familiar, even if

our methods are somewhat rough and ready, we are also familiar with the notion of moral education, but this last has usually taken the form of enforcing the acceptance of certain ideas and certain forms of conduct, sometimes by means of fear alone, almost always without regard to the nature of the motives which actually induce the child to accept them. Moral education has too often crippled rather than furthered emotional growth. We now recognise that a child's emotional inheritance cannot be expected to unfold and develop normally in unsuitable conditions any more than a plant will develop normally in the absence of sunlight, air, and suitable soil.

The facts of emotional development to which I have briefly referred were originally brought into sharp relief in the course of psychoanalytic work. There is nothing, however, in what I have described so far, which could not be observed or inferred apart from the method of Freudian analysis. If psychoanalysis has made an indispensable contribution here, it is in pointing out that the principle of repetition applies in a thorough-going manner to emotional development in general, and in insisting, consequently, on the decisive importance for future development of feeling aroused or inhibited in infancy and early childhood.

Up to this point I may hope that what I have said has not met with any strong emotional objection on the part of my audience. That is to say, you may agree or disagree, but it is unlikely that anything I have said has aroused definite repugnance, in the shape of anger, or disgust, or fear. But I have now to introduce and illustrate the specific contributions of psychoanalysis to my subject, and these, in the first place, go considerably beyond the findings of introspective and behaviouristic psychology, and, in the second place, they are not in line with common prepossessions on the subject of human nature.

In the illustration which I have used of a boy's developing disposition towards hatred, it is specially noteworthy that the secondary hatreds do not depend on a conscious recollection of the primary one. The boy does not say to himself, "This man reminds me of my father because he is in authority over me, therefore I hate him." If he did, it would tend rather to enable him to get control of his disposition to hate, since the sensible course would be to discount the resemblance and judge the person concerned on his own merits. But, as a rule, the case is quite otherwise. The feeling of hostility rises in him immediately and as it were instinctively, without any conscious reference to its original cause. It derives in fact from the past, but it appears in consciousness in apparent relation solely to the present. Thus the persistence and activity of feelings so derived has nothing to do with conscious recollection of their origin. Now in this connection a Viennese physician, Josef Breuer, disclosed nearly fifty years ago a fact of great importance. Everyone knew that events in consciousness, which were accompanied by intense interest and strong feeling, are vividly impressed on conscious memory and may remain unforgotten over the whole life. Breuer's observations showed that an apparent reversal of this principle is also possible so far as conscious memory is concerned. He showed that

experiences charged with strong feeling and vividly impressed may nevertheless be actively and completely excluded or "repressed" from conscious memory, so that the person concerned is quite unaware that the experiences in question ever occurred. This happens if the experiences in question either are or become too painful to be tolerated in consciousness. He showed further—and this is the important point—that such inhibited or repressed memories are not deprived of influence on the subsequent life of the individual, on the contrary, they may persist the more potently, although unconsciously, by reason of their exclusion from conscious control. Everything then goes on as if they were unconsciously remembered in their original form, unmodified by reflection. They retain their hold on the feelings of the individual and influence his subsequent emotional life in defiance of his reason, from the influence of which they are withdrawn. Breuer's original observations were later confirmed by Freud working in conjunction with him, and they have since been confirmed by numerous workers, so that they are now accepted by all competent persons.

The simplest instances which one can give of this peculiar mental situation are the morbid ideas and feelings, familiar since the war, which torment sufferers from shell-shock. Shell-shock, in its proper meaning, is a form of emotional shock. The sufferer remembers nothing of the ideas and emotions with which the explosion of the shell filled him. Yet these persist unconsciously, and the fact that they do so is evidenced by the uncontrollable re-arousal of the feelings in question in defiance of reason, and by the reappearance in consciousness of similar but now quite irrational ideas, whenever the circumstances of the man's present life are capable of forming an association with them and instigating their explosion. Thus in addition to the organised unconscious repetition of the past in the present, in so far as it is taken up into and made use of in connection with present interests, we have a form of disorganised (or dissociated) unconscious repetition in which the past persists unaltered and influences feeling and activity in defiance of reason and the present. This is far commoner than at first we might suppose.

It was this observation which, in the hands of Freud, led to the gradual development of the psychoanalytic method of mental exploration, and finally to the illumination of some of the most obscure features of our emotional development and of our mental structure generally.

Perhaps I should say a few words here on the present situation in reference to Professor Freud's work. All persons who have made use of Freud's technique (the value of which is not in dispute) have confirmed his findings so far as facts observed are concerned. The facts observed are indisputable. Differences exist only as to the interpretation which should be placed upon these facts. As to this, it must be admitted that Freud's interpretation has at first sight a disagreeable character, while the views of opposing schools, like those of Jung and Adler, appear much less repugnant. For this reason the latter views are at first the more attractive. Considerations of this kind, however—of

what is pleasant, what is not—should have nothing to do with a question of fact. If we put such considerations aside, as we ought to do, Freud's interpretation seems to be that which most naturally and easily fits the facts, while the views of Jung and Adler appear more strained, containing, as they do, serious difficulties which have never been smoothed out. This situation is not affected by the circumstance that both Jung and Adler have made most valuable observations, which everyone accepts, since these observations supplement without contradicting the Freudian position. My own experience leads me to believe that the general acceptance of Freud's main position by instructed opinion is only a matter of time. It is therefore with his views that I am concerned here, but in illustrating them I must confine myself to a single central feature. In order to discuss this we must go back to earliest infancy.

According to the findings of psychoanalysis, and for that matter of common observation, the affections of a human being are in the first instance, that is in earliest infancy, directed solely towards itself. The distinction between self and the environment is not one which the infant is at first capable of making, while all things are at first appreciated simply in relation to their capacity to yield pleasure or pain in the course of the satisfaction of the infant's needs. Thus the earliest stages of emotional development are thoroughly, though unconsciously, self-centred. Following on this stage, however, as development proceeds, the beginnings of altruistic feeling appear, and the infant becomes for the first time capable of affection towards a fellow creature clearly distinguished from himself. He, or she, becomes for the first time a truly social creature. The capacity for such affection directed towards others shows itself in the first instance, naturally enough and as everyone knows, towards the persons already associated with the satisfaction of previous and existing needs, that is, normally, towards mother, or nurse, or both. Later the father normally comes to share in it.

Now, in the light of what I have already said, you will not be surprised to hear that we regard this particular step in development and the further emotional development which follows it as of very great importance. It is the first appearance of altruistic or truly social affection. Out of it will grow all the later social affections of which the child becomes capable, it will remain the prototype of these, and we find, in fact, that the character and activity of these later affections will be determined in large measure by the course which this earliest development follows in interaction with external circumstances.

But the method of psychoanalysis has revealed a further most important fact. The affection in question does not manifest itself merely in the form of those feelings of admiration, friendliness, tenderness, trust, and the like, which will be taken up into and characterise in various degrees many later social relationships, it may include all these, but, immature though it be, it resembles much more nearly the state of feeling which we know in adolescence and later life as that of being

in love that is to say, it resembles most closely those later affections which are definitely sexual. In other words, our earliest infantile attachments appear as the commencement and foundation not only of truly social feeling in the wide sense but also of normal sexuality. At their commencement these two streams of feeling are inextricably intertwined and appear to spring from a common sexual root.

That such a connection should exist is not, perhaps, very surprising, if we view it in the light of our racial history or our biological past. It is no more remarkable that our social feelings should develop post-natally in association with sexual feeling (in contradiction with the demands of adult life) than it is that our circulatory system should develop pre-natally out of a system of gill arches adapted to life in water but hopelessly out of touch with the needs of life in air. Both sets of processes are equally developmental, and in the one case as in the other we are faced, no doubt, with a partial recapitulation of the racial past.

On the other hand, that such a connection should exist and have gone so long unperceived is very remarkable, but this is partly explained by further circumstances likewise laid bare in the course of analytic investigation. We find that sexual development in Europeans goes forward not in one but in two stages. We have, first, the early infantile stage, to a feature of which I have just referred. In this stage, in which love is directed normally, as we have seen, mainly towards the parents, feelings and impulses of an unmistakably sexual although immature character first arise together with feelings of affection and tenderness. This stage, we may note also, is more or less bisexual. Now in the nature of the case the first-mentioned feelings, the sexual feelings in the narrow sense of the term, can receive no very adequate satisfaction. From the start they are doomed to relative disappointment. Not only is this the case, but among Europeans at any rate (not apparently in all races) as development, and especially ethical development, proceeds, all that is overtly sexual during this stage undergoes repression and becomes unconscious under the influence of feelings of shame, disgust, fear, and later anger, which arise in that connection to that end. This process of repression, which is usually complete about the age of five or six years, is in part, no doubt, the effect of early education, since any overt manifestations of sexuality in infancy are usually discouraged, but there is reason to believe that it is in any case organically determined, sets in, that is, in the course of development independently of education. It is obvious, then, in the first place, that this first stage of sexual development belongs to that part of our personal history, namely infancy, which is always more or less lost to conscious memory, and, in the second place, that those feelings, ideas, and associated memories, which were plainly sexual and have for that reason undergone repression, belong to those portions of our early emotional history which as a rule we *cannot* remember under ordinary circumstances. Hence it is impossible for most of us to confirm directly from personal memory, apart from psychoanalytic investigation, the existence of this early stage, while

at the same time those feelings which serve the repression of it in our own minds tend to cause us to overlook or misinterpret its manifestations in our children

This first stage of sexual development which undergoes repression is normally followed, at least in Europeans, by a stage of sexual latency, in which all the manifestations of direct sexuality are more or less completely in abeyance. This stage of latency is a somewhat variable feature, its degree and duration differ from one individual to another. It is followed again by the second stage of active advance, with which we are all acquainted, in which feelings and ideas, again of an unmistakable sexual quality, reappear in consciousness. These continue to develop, slowly at first, later more rapidly, until adolescence is reached, when, with the maturation of the genital glands, the full expansion of the sexual instinct sets in, with the rapidity and force, and, one may add, with the remarkable consequences in the intellectual and the ethical sphere, familiar to all normal persons. Thus the early stages of our sexual development are hidden from us, the later alone remaining apparent in consciousness.

We have then at least two reasons to attach importance to this particular feature of emotional development in infancy. Not only do the feelings which are called out in the course of it exert an influence on the whole of the individual's subsequent social life, the whole of his subsequent sexual life is likewise influenced.

Let me follow this development a little further. I have pointed out that an infant's first attachment is naturally to those who are already associated with the satisfaction of its needs, that is, usually, to its mother or nurse. This first attachment is irrespective of the infant's sex. A little later, however, the actual sex of the child begins to express itself, aided, no doubt, by the normal hetero-sexual preferences of the parents themselves in reference to their children. We find then, sooner or later, in the course of normal development, that the dominant feeling is for the parent of the opposite sex. In the case of boys, of course, this involves no change. In the case of girls a change is involved. It is at this point that the so-called Oedipus situation comes into being. Where one parent is predominantly loved, it is only natural that some degree of jealousy and consequent dislike should be felt for the other. For the other parent, in so far as he, or she, receives affection and consideration from the parent who is loved to the relative exclusion of the child itself—again the normal situation—comes quite naturally to be regarded as a rival whose disappearance is desired. It is in this way that the Oedipus situation comes into being and persists, until the repressions, which herald the arrival of the latent period, set in and become dominant. From this point on, the directly sexual elements in the love of the parents usually disappear from consciousness, while their sublimated representatives, affection, tenderness, and respect, usually remain.

Thus, when the second period of sexual advance sets in, the parents

have vanished to all appearance from the field of sexual feeling. But we have already seen that disappearance from consciousness under repression is not equivalent to extinction. The original objects of infantile sexual feeling with the experiences associated with them persist under repression as unconscious images, after the manner of repressed mental material generally, and still retain a weaker or a stronger hold on the feelings of the individual. We find that the further development partly consists in an unconscious transference of erotic feeling from the image of the parent originally loved to persons (finally) outside the limits of the family. It follows that the earliest attachments are to persons associated in some way with the parents, though not necessarily consciously associated, since apart from this, constituted as we are, such transference could hardly take place. There must be some bridge over which energy can flow from the one image to the other. Where such transference is fairly direct, the trend of the earliest attachment often makes itself unconsciously felt both in the characteristics of the persons who exercise attraction and in the character of the attraction itself. Such persons are often older than the boy or girl who is attracted by them. That is common knowledge in the case of both sexes. Further, in the case of boys, they are often loved as queens or goddesses, rather than as mates in the true sense, and, making the necessary changes, the same is often true of the early attachments of young girls. The inhibition also, which lies on the physical side of the primary infantile attraction, often extends to some extent to these new objects of love, so that there may be something repellent, rather than attractive, in their association with that side of sexual feeling. Later on this child-like attitude is, or should be, replaced by one in which lovers meet on terms of relative equality, while the two streams of directly sexual and of sublimated feeling become once more confluent in the experience of fully developed love.

There are two points, then, in all this, which need to be grasped. The first is that the original infantile sexual attraction, unconscious under repression, tends for that very reason to retain its force and to exert an influence on the formation of all later attachments. The second point is, that full sexual development consists in attaining freedom from this compulsion and from the inhibitions which may result from it, in respect of all those feelings which, in conjunction, make up adult love.

Where such freedom is not attained, a variety of consequences may follow. For the sake of clearness as well as brevity, I will refer here only to two possible situations of the many which may arise.

Take first the situation which arises in cases where the normal process of development and detachment has failed to take place, and the individual has remained, unknown to himself or herself, at the infantile sexual level.

Assuming that the person concerned is otherwise normal the situation is somewhat as follows. He, or she, has passed through the first or infantile stage of sexual development. Repression has ensued and the

recollection of this stage has been obliterated from conscious memory. But a liberation of feeling from the now unconscious images of the parents, as they were known or imagined to be in infancy, has failed to take place. In the unconscious they are still loved or hated as they formerly were. As physical and mental growth proceeds and the sources of sexual feeling develop also, all direct sexual feeling tends to be sucked under—so far as its application to real persons in the real world is concerned—by the attraction exerted by these primary unconscious images and to come under the inhibition beneath which they lie. It is clear that such an unconscious fixation (as it is often termed) of the love impulses to such a degree must have important results in consciousness itself. These results will be both positive and negative: positive in so far as feeling will tend to be determined towards the actual parent concerned who is the living representative of the unconscious image, negative, in so far as there will be a failure to show feeling where a normal person would show it.

Let us take positively determined feeling first. Powerfully inhibited as it is, this can usually only show itself in a more or less desexualised or sublimated manner. There may be a more than ordinary degree of tenderness, respect, and the like, for the parent involved, combined too often with an abnormal degree of submission to the parent's authority, and dependence on the parent's protection—for the satisfaction of infantile love lies in being loved more than in loving. The person concerned may be all too satisfied with life in the parental home, and very unwilling to leave it and face life on his or her own account. All this is often accepted as evidence of exceptional filial feeling, and may even be considered praiseworthy by the thoughtless. It is on the negative side, in the gap in conscious feeling, that the sexual nature of the unconscious source of this attitude comes plainly to light. The individual fails to fall normally in love in adolescence or early maturity. Marriage is shunned, or entered upon from loveless motives, often with much resulting unhappiness. Lastly, when sexual relations in marriage are attempted, psychical impotence or frigidity, in the male or female respectively, is found to result. It results because the sexual act itself and the feelings normally associated with it, the most direct possible manifestation of sexuality, cannot escape from the effects of the inhibition which their close though unconscious association with the image of the loved parent necessarily involves.

You will note that I have chosen an extreme example. Naturally, all degrees between such a complete unconscious fixation of the sexual feelings and the normal situation of practical freedom are actually found in practice. If, indeed, by the term "normal situation" we meant the average situation of human beings in general, we should have to say that the normal situation lay somewhere in between these two extremes—nearer health of course. For while complete impotence in men is relatively rare, degrees of relative impotence are common, and frigidity in women is certainly much commoner, while marked degrees of partial frigidity are commoner still. Both conditions are the cause

of a very great deal of married unhappiness. You must not suppose, however, that either impotence or frigidity is determined solely in all cases in the way just described. Other factors may condition it, but the factor just mentioned is one of the most important and is sometimes the sole cause.

Let me now briefly describe another possible, not uncommon, and equally unfortunate result, in cases where a strong infantile fixation exists, but the repression is not so strong as to inhibit physical sexuality altogether.

It is, we must remember, to the image of the parent, as he or she was known or perhaps imagined in infancy, not to the parent who exists in real present life, sometimes a very disappointing person, that the desires of the individual are unconsciously bound. For instance, the unconscious image of the mother may be from the child's point of view the embodiment of all beauty, tenderness, and help. From this there may arise in some persons an endless search for the "ideal" mate in real life, and it is in this way that what is sometimes called the "Don Juanism" of the sexual life of some men takes origin, since Don Juan is the classic literary example of the male type. These unhappy persons pass from one love affair to another seeking satisfaction which perpetually eludes them, and leaving unhappiness behind them, as each new object of desire proves somehow inexplicably wanting. It is the forgotten ideal of their infancy whom they unconsciously seek, and hence they can never arrive.

By an error of judgment, not uncommon on this side of human nature, such persons are often described, in literature for example, as love heroes and the like. Their numerous love affairs are regarded as evidence of their unusual capacity for this emotion. But the truth is that they are cripples. Their love affairs are evidence of their weakness, their inability to love, not of their strength.

Such reversals of judgment are not uncommon in analysis. Thus, in the case previously discussed, the filial feeling which is shown is often regarded by its bearer and only too often by the parent in question as a virtue, while from our point of view it is a weakness and a heavy disadvantage.

I should like to conclude these illustrations with the briefest reference to a peculiarity of male sexuality which is so common that it is sometimes accepted as a normal feature. I refer to a positive dissociation in feeling between direct sexual attraction on the one hand, and tenderness, esteem, sympathy, and the other components of fully developed love on the other, so that these two groups of feelings tend to be mutually exclusive. In the extreme case, for instance, we get a man who is attracted physically by women whom he cannot respect, while women whom he can respect may call out affection and admiration but not direct sexual feeling—a disastrous situation, minor degrees of which, however, are common. While the infantile determinants of this situation are, as a matter of fact, somewhat complicated, it is not difficult to

see in a general way, in the light of what I have already said, how naturally, though unfortunately, such a split in feeling tends to come about

In discussing our emotional development and a few of the practical consequences of the course which it follows, the main stress in what I have said has fallen on the sensual side of sexual feeling. The reason for this is, that it is with failure to develop on this side of human feeling and with its effects that practice makes us most familiar. I was desirous also that this aspect of the matter, which is fundamental from a biological standpoint, should be placed in a clear light. But I should be sorry if I misled you into thinking that we regard the sublimated sexual feelings, or any of our higher feelings, as in any way of less importance than the directly sexual ones. That is not the case. It seems to me plain on the surface of the social situation that these feelings are of the last importance for the future of our civilisation and our culture. It should not be necessary to say that the fact that some of the most important of these feelings are unconsciously interlocked with directly sexual feeling does not diminish by one iota their value to us and to the future of mankind. That fact, on the contrary, affords a powerful motive for the unbiassed psychological and physiological study of the sexual instincts. I need not say, either, that we are quite unable to share any view, however it may describe itself, which attributes a degraded character to functions which are the foundation of life and love in human beings.

I should like to conclude this paper with two illustrations from life, the first of which may serve to show us how powerful the second how lasting, our infantile affections and longings are, immature though they be. The first illustration is taken from the life of Gustav Theodor Fechner, the second from Leo Tolstoi.

Gustav Theodor Fechner,¹ professor of physics at the university of Leipzig, was a man of outstanding intellectual and emotional power. Born in 1801, he passed his medical examinations at the age of twenty-one. Poor as he was, he decided, instead of practising, to devote himself to physical science. Up to the age of thirty-eight, for seventeen years therefore, his life was passed in unremitting and, unfortunately, unremunerative intellectual toil. His publications during this period were little short of monumental, and at the same time his scientific work, consisting of experimental researches in his own and in allied sciences, was excellent. Some of it is classical. At the age of thirty-eight, as a consequence, it was thought, of continuous strain, overwork, poverty, and an eye trouble brought on, or supposed to be brought on, by his observations on visual after-images (a classic piece of investigation), he suffered a terrific nervous breakdown which lasted three years and cut him off entirely from active work. So inexplicable and so malignant did his sufferings appear, that when after three years he began to get well, both he and others regarded his recovery as a sort of divine

¹ I abridge this account of Fechner from William James (*A Pluralistic Universe*, p. 145 et seq.), using James's words as far as possible. Comments are, of course, mine.

miracle. It was, in fact, his religious and cosmological faiths which saved him, and thenceforward one great aim with him was to work out and communicate these faiths to the world.

What, then, were the faiths with which he emerged from this experience? They were very remarkable ones.

"The original sin of our thinking, according to Fechner," says James,¹ "is our inveterate habit of regarding the spiritual not as a rule but as the exception in nature. Instead of believing our life to be fed at the breasts of the greater life, our individuality to be sustained by the greater individuality, which must necessarily have more consciousness and more independence than all that it brings forth (note the character of these metaphors), we habitually treat all that lies outside us as so much slag and ashes of life only, or, if we believe in a divine spirit, we fancy him on the one side as bodiless, and nature as soulless, on the other. The flowers wither at the breath of such a doctrine, the stars turn into stone, our own body grows unworthy of our spirit, the book of nature turns into a volume on mechanics, and God becomes a thin nest of abstractions." To Fechner this doctrine came to seem incredible.

For Fechner nature and the whole universe became alive and conscious of its life. The vaster orders of mind go with the vaster orders of body. The whole earth is alive and conscious as a vast yet unitary spirit. Just as in ourselves the eye sees and the ear hears, the eye knows nothing of the ear nor the ear of the eye, yet our consciousness, which includes them both, sees and hears at once through each of them, so the earth. Her consciousness includes all our experiences, and not only ours but those of every animal and plant that breathes her atmosphere. And beyond the earth comes the whole solar system, and so from synthesis to synthesis and height to height until an absolutely universal consciousness is reached, the consciousness of God.

I regret that I have no space in which to repeat some of the arguments by which Fechner supports this conclusion. They are much more interesting and remarkable than might be supposed. However, my present interest is different.

"In his system," says James, "the supreme God marks only a sort of limit of enclosure of the worlds above man." (One comes ultimately, no doubt, to something which includes everything.) The object of Fechner's passionate belief is the earth soul. The Earth is our special human guardian angel, we can pray to the Earth as men pray to their saints. The thought of the perfections of her life moves him as nothing else can. "Think of her beauty, sky-blue and sunlit over one half, the other bathed in starry night, reflecting the heavens from all her waters, myriads of lights and shadows in the folds of her mountains and windings of her valleys, she would be a spectacle of rainbow glory, could we only see her as she is. Green would be her dominant colour, but the

¹ *A Pluralistic Universe*, p. 150 et seq.

blue atmosphere and the clouds would enfold her as a bride is enfolded in her veil—a veil the vaporous and transparent folds of which the Earth, through her ministers the winds, never tires of laying and folding about herself anew. Yes! The Earth is our great common guardian angel, who watches over all our interests combined.”

“On a certain spring morning,” says Fechner, “I went out to walk. The fields were green, the birds sang, the dew glistened, the smoke was rising, here and there a man appeared, a light as of transfiguration lay on all things. It was only a little bit of the Earth, it was only one moment of her existence, and yet, as my look embraced her more and more, it seemed to me not only so beautiful an idea, but so true and clear a fact, that she is an angel—an angel so rich and fresh and flower-like, and yet going her round in the skies so firmly and so at one with herself, turning her whole living face to heaven and carrying me with her into that heaven, that I asked myself how the opinions of men could ever have spun themselves away from life so far as to deem the earth only a dry clod. But such an experience passes for fantastic. The earth is a globular body, and what more she may be one can find in mineralogical cabinets.”

I should be sorry to spoil with comment what I have just read. It is not difficult to see who it is who has returned in the person of Cybele, the Earth Goddess. The dear companion, the divine mother, is Fechner's once more, and with this tremendous sublimation he passed out of suffering and misery into happiness and health. After that he could and did work as hard as ever, but there were no more breakdowns.

My second citation is from the diary of Tolstoi in his old age. “I go over,” he writes in his private diary, “all the people I have loved, not one is suitable to whom I can come close. If I could be little and snuggle up to my mother, as I imagine her to myself! Yes, yes! Mother whom I called to when I could not speak, yes, she, my highest imagination of pure love, not cold divine love, but earthly, warm motherly. It is to that that my battered weary soul is drawn. You, mother, you caress me. All this is senseless, but it is all true.” Tolstoi's mother died when he was two years old.

A Geological Reconnaissance of the Linville-Nanango District.

By E C TOMMERUP, B Sc, A A C I

One Geological Map

(Communicated by Dr W H Bryan to the Royal Society of Queensland, 28th April, 1930)

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I—INTRODUCTION

The following paper is an abridged* description of studies made on the geology of a large area situated between Linville and Nanango, Queensland. The information was gathered during numerous traverses made by the writer when stationed in the district on forestry work.

Little geological work has been done in the district, but considerable assistance can be derived from various reports on some scattered mining "shows" associated with the edges of the granitic intrusions. The nearest systematic surveys south of the area are those carried out by Reid,¹² Reid and Morton,¹³ and Hill¹⁴ on the country between Esk and Ipswich. It is probable that the Esk series of shales and conglomerates form a continuous belt from Esk to Linville, and that the Esk andesitic stage forms a practically continuous strip from east of Esk to beyond Goomeri in the north.¹⁵

The writer has attempted to correlate and classify the various rock formations of the district, but does not regard the classification as either

* A contour map of the area, together with a more complete account of the area with details of actual outcrops, portion numbers, descriptions of rock specimens, and other important though minor details, has been deposited in typescript form in the library of the Society, and will, it is hoped, be found useful by future workers.

complete or final. He hopes, however, that this paper will serve as a basis for further work, and that it will assist in the geological mapping of Queensland.

II—THE BRISBANE SCHISTS

What are regarded as outcrops of the Brisbane Schists appear north of the area at Wondai and Manumbar,¹¹ and in the south near Crow's Nest,¹² whilst east of the area Brisbane Schists form a huge belt.¹³ An outcrop of typical light-brown hard schistose shales of this series occurs along Rocky Creek where the Yarraman-Nanango road crosses it, they strike N N W and dip 80° E. In the creek bed jasper pebbles are found some of which carry radiolarian casts. On Poi 292 Cooyai, serpentine rock may be seen in an old shaft. Outcrops of typical and almost vertical N N W-striking schists are to be seen close to Yarraman township, on the Upper Yarraman road. A considerable extent of slates, hard sandstones, and quartzites outcrop to the north and east of Nanango, and these also appear to belong to this formation though Rands¹ regarded them as belonging to the Gympie Series.

III—THE GYMPIE SERIES

A number of patches of massive, jointed, hard, fine-grained, dark-coloured, bluish grey to black metamorphosed slates of somewhat doubtful age outcrop in various places in the district, frequently associated with granite intrusions. Usually no dip or strike is discernible. Fine quartz veins may be seen in this rock, which is regarded as belonging to the Gympie Series on account of lithological similarity with outcrops in other parts of the district¹⁴ which contain fossils.

A typical outcrop is seen close to Benarkin railway station. Further outcrops have been described by Ball^{15 16 17} from the neighbourhood of Taromeo. Mr Ball's work has been incorporated in the accompanying map.

Several patches of these slaty rocks may be observed between Benarkin and Yarraman Creek. They strike roughly N W. and are practically vertical. Their positions are given on the map.

IV—THE ESK SERIES, ANDESITIC STAGE

I have to report the find of the Goomei Volcanics farther to the south than mapped by Mr Reid in his report.¹⁸ Typical andesitic agglomerates and intrusive andesites are to be seen near Marbletop east of Nanango, and on adjacent lands. The following is Mr A K Denmead's description of a microslide of a specimen taken from near the boundary between R 456 and the northern end of R 299 Avoca — "A fine-grained rock exhibiting a pronounced fluidal structure under the microscope. The groundmass consists of rods and needles of plagioclase, epidote, magnetite, and chlorite in a more or less devitrified glass. There are phenocrysts of plagioclase feldspar, more or less decomposed, and of hornblende partially or entirely converted to a mass of chlorite and epidote. Name andesite."

The whole of this area is made up of intrusive andesites and masses of andesitic agglomerates (or perhaps tuffs) which occur on top of the Brisbane Range and in the beds of Burnettine Creek below. Probably the western boundary of the series passes through Por 279 Coolabunia, and west of Paradise Creek in R 299 Avoca (51v). It will be noticed that an imaginary extension of this boundary line leads roughly along the Blackbutt Range for about eight miles. There is thus the possibility that this range is a fault scarp. There is much evidence of faulting showing in the railway cuttings between Benarkin and Linville.

The writer was able to follow the andesite series continuously south from Goomeri to the head of the Brisbane River and beyond Mount Stanley at least as far as the junction of Avoca Creek with the Brisbane River. This series covers a wide area and consists of massive andesitic agglomerates and intrusives with perhaps tuffs, &c. The agglomerate is perhaps the most common type, and along the road from Goomeri to Mount Stanley down the Brisbane River (west branch) it consists mainly of angular fragments of andesitic rock embedded in a matrix of what appears in the hand specimen to be lava and perhaps also consolidated tuffaceous material.

On the east branch of the Brisbane River a few miles below Mount Gibbarnee, the agglomerate consists of pebbles from very small up to boulder size embedded in a matrix of andesitic (?) lava. The pebbles are sometimes pinkish, due probably to oxidation, but many are of grey andesite which exhibits phenocrysts of plagioclase and pyroxene set in a fine-grained groundmass. Occasional pebbles of milky quartz and chert also occur. Along the west branch the series is seen forming cliffs in several places, and disjointed and irregular bedding may be seen. There does not seem to be any definite dip or strike, but joint planes are numerous. Nevertheless one can sometimes make out a general N and S trend and a general dip of 50-60° E N E can be observed on T R 59v.

Rands¹ and Jackson² have visited Gooroomjam Creek, which rises in the Brisbane Range near the eastern edge of the andesite belt. These geologists studied the ore-bodies which exist there and described the country rock as fine-grained diorite. Recently the area has been mapped by McGrath and Jennings,^{3,4} and their reports indicate that generally speaking the rock on the western side of Bunya Creek on R 154 Gallangowan is a porphyritic hornblende andesite, whilst that on the eastern side is a more typically textured andesite. This distinction also holds for the northern end of R 329 Avoca. Near the head-waters of Gooroomjam Creek there are granodioritic intrusions in massive diorites. In short, this locality seems to have been a centre of disturbance, on the edge of the andesitic belt.

V—THE ESK SERIES, SHALE STAGE

The next series of rocks to receive consideration comprises a number of outcrops of shale and conglomerate situated as follows —

(A) A large outcrop in the vicinity of Tarong. This series consists of coarse conglomerates and shales. The pebbles are made up of

rhyolite, chert, &c some large (12 in diam), but usually about 3 in diam and smaller. In some places a slight secondary pressure or chemical metamorphism has produced a gritty textured quartzite.

(b) An outcrop of grey shale and conglomerate occurs on Por 25 Cooyar, and dips 15° E N E.

(c) On T R 369 Cooyar, at the head of Oaky Creek, conglomerates very similar to those seen near Tarong outcrop. They are definitely overlaid by basalt on the eastern corner of the reserve. The Spring Creek gorge near-by, which is a couple of hundred feet deep, is cut entirely in basalt. The relationship of this conglomerate bed to the granite was not determined, but the conglomerate is almost certainly younger.

(d) A patch of conglomerate and shales occurs on Upper Yarraman Creek, accompanied by a small seam of steam coal in Poi 84v. The seam is said to be about 6 in thick and is accompanied by fossils. An analysis of a sample of this coal gave the following results —

	Per cent
Moisture at 100° C	5.1
Volatile matter	26.3
Fixed carbon	55.2
Ash (grey colour)	13.4
	<hr/> 100.0

The conglomerates exposed in the gully consist of numerous pebbles of typical Brisbane Schist, of typical black slates like those regarded as Gympie Series, of sandstone, banded cherts, milky quartz, rhyolite, &c, set in a sandy or mudstone matrix. The conglomerate beds are mingled with layers of grits, sandstones, and shales, and exhibit current bedding. Much secondary red ferruginous staining has been produced by percolating waters. Mr Ball²¹ has also examined this locality and he quotes dips of 10 to 15° N N W on Yarraman Creek.

(e) Very similar conglomerate beds are seen near Kooralgin, these dip at 25° S E. This outcrop is also overlaid by a large outcrop of basalt in Poi 153 which appears to be intrusive in this locality.

(f) Mr K P McGrath,²⁴ has mapped an area of fossiliferous conglomeratic shales along Moonarumbi Creek in R. 245 Monsildale which are probably assignable to the Esk Series. Conglomerates are also to be found farther south.²⁵

(g) Jack² mentions conglomerates below basalt on Por 5v Burrandowan.

On lithological grounds the writer regards all these outcrops as belonging to the Esk Shales (Ipswich basal conglomerate stage).²⁰

Esk shales outcrop on the southerly slope of the Blackbutt Range and are seen along the Linville-Benarkin railway and along the main road.⁸ An examination of the railway cuttings revealed that there was much evidence of faulting in this locality, the dips varying considerably over short distances 10° E to 60° E being approximate limits, with a

general strike NNW. The beds are conglomeratic with pebbles of chert, rhyolite, and what appear to be fragments of Brisbane Schist and Gympie Slates, but no granitic or basic rocks. Fossiliferous beds are present. Numerous interbedded dark greywackes occur, notably between the 75-78 mile posts. Some are narrow bands, others thick, the variation ranging from 10 to 150 ft. These greywackes can be regarded as sandstones composed of quartz, felspar, rock fragments, and other detritus from some weathered basic rock. Typical Esk shales and conglomerates outcrop at several points along the Brisbane Valley railway south of Linville.

A specimen of a basic rock from part of the (?) Esk Series, collected near Bunt Hill Forestry Barracks (position marked on map with an asterisk), was sectioned and described for me by Mr. Denmead as follows:—"A elastic rock composed largely of fragments of andesite and of some fine-grain sedimentary rock (slate or shale), partially kaolinised felspar crystals are numerous. Very scarce angular quartz fragments also occur. The few ferro-magnesian minerals are very decomposed and are now represented by leaves and irregular masses of chlorite which occur interstitially. A few iron ore fragments are present. The groundmass is not clearly defined. The rock is an andesitic tuff."

VI—IGNEOUS ROCKS

The igneous rocks of the area are rather complex and not easily correlated. Three main types can be distinguished, and are indicated on the map—

- (A) A series of grey granodiorites which are younger than the intruded Gympie Series but older than the overlying Esk beds.
- (B) A series of andesitic rocks which, to avoid confusion, are termed porphyrites, though some outcrops are perhaps not precisely true to label. These rocks are apparently closely associated with the granodiorites.
- (C) The basalts, which outcrop along the Cooyai Range and elsewhere, and which are younger than the Esk Shale Series.

(A) THE GRANODIORITES

These rocks usually contain a sufficiency of quartz, though Mr. Ball^a quotes syenite from the foot of Mount Melleria and from other localities. Associated with the granites, too, are small flows of trachytes and rhyolites. The Taromeo, Nanango, and other areas have been mineralised and several shafts have been operated in the past for ores of copper, silver, gold, and other metals which are found in close proximity to the granite outcrops.

Numerous outcrops of granodioritic rocks are found in the area, and all those so far described* are marked in on the accompanying map.

* A fuller description of the outcrops will be found in the original typescript of this paper deposited in the Society's library.

Those described from the Nanango Goldfield,¹ Taromeo district² ¹¹ ¹² Gooroomjam Creek,³ ¹⁴ Mount Monsaldale,⁷ ¹⁵ Jumna Creek,⁸ Kunmoon,¹⁶ and Dattu Dattu,⁹ ¹⁰ are taken from literature, the remainder are personal observations

In several localities where the granites intrude the (1) Gympie Series an interesting type of contact breccia is found in the granitic aureole. Examples may be seen on the Gilla-Kooralgim road and old Yarraman-Nanango stock route. The contact zones are marked by outcrops of laminated sericitised rhyolites associated with peculiar volcanic agglomerate consisting mainly of a dark felsite containing much quartz, small phenocrysts of feldspars, traces of mica and ferro-magnesian minerals and xenoliths of other associated rocks. On Cooyar Creek in Poi 42v fluxion structure is clearly seen in felsite associated with altered andesites. The same phenomenon is described from other localities¹ ⁴ ⁵ ⁶. Evidently the punching magma distends and cuts the country rock and produces a crush breccia which is then indurated and a kind of volcanic agglomerate is formed (cf Tyrell, "Principles of Petrology," p 20)

(B) THE PORPHYRYTES

In numerous places in the area the granodiorites apparently pass continuously into porphyrites. These junctions, however, need special investigation. Miss D Hill (personal communication) has examined the junction of the granite and the porphyrite at Cooyar Creek crossing, and considers that the granite is intrusive into the porphyrite. The porphyrite outcrop is fairly typical of those in the district, and consists of phenocrysts of plagioclase undergoing saussuritization, small phenocrysts of chloritised amphibole and small crystals of pyrite may also be observed. Similar material outcrops in Poi 42 Cooyar and at Din Din (C and W R 54 Cooyar). At 83½ m on the Linville-Benarkin railway a basalt containing feldspar, olivine, ilmenite, secondary quartz, epidote, and pyrite may be seen associated with a granitic intrusion.

(C) THE BASALTS

Ball¹ describes a fayalite basalt from Mount Mollera near Taromeo, he regards the mountain as the site of an extinct volcano, and notices that "the lava flows have not passed over the Ipswich beds but abut against their edges as against a cliff (but probably they are of later age than the Ipswich) "

The Cooyar Range basalts (or andesites) are fairly typical in that they weather to give a red loam soil, and also because they contain, in some localities, numerous inclusions of foreign rocks, and when this agglomerate weathers it exhibits a curious "puddingstone" appearance, patchy white xenoliths standing out in contrast to the weathering matrix proper, which is of a ferruginous red hue. This basalt extends all along the Cooyar Range and for some miles on either side. It overlies the

conglomerate beds regarded as Bak Series and also overlies* granite. It peters out towards Nanango. It is probably contemporaneous in age with the Mount Mollera basalt, with the Tingoora and Boat Mountain basalts,¹⁶ and with the Main Range basalts—that is, with the Upper Tertiary basalts of Professor Richards.²² Specimens from cliff boulders from R 510 (1v) at the head of Cooyai Creek proved to be basaltic glass or tachylite, associated with which is an ironstone rock of a slag-like appearance. From the nature and position of this outcrop it seems probable that the junction of the Great Dividing Range, Bunya Mountains, and Cooyai Range is the seat of a Tertiary centre of vulcanicity (*See* Harker, "Petrology for Students," p 207)

The Bunya Mountains appear to be composed entirely of basalt. Jack⁴ describes basalt from the mountains at the heads of the Boyne River, Jumna and Ironpot Creeks. He mentions, too, that sedimentary strata occur interbedded with the basalt flows on the slopes leading up from Jimbour to the Bunyas.

On part of S F R 316 a somewhat curious agglomeratic rock exists, in the hand specimen fragments of chert, slate, &c, may be seen set in a dark groundmass, and the rock is not unlike specimens from the Bak andesitic stage. A sample of this rock selected from the western end of Por 53v was sectioned for me by Mr A K Denmead, M Sc, and his report on it is very interesting —

"A medium-grained rock of even texture with the following minerals in order of abundance —

- 1 Felspar usually much kaolinised, where recognisable belonging to the plagioclase group. Occurs in sub-idiomorphic to extremely irregular individuals. One or two individuals of fresh potash felspar (microcline) occur in the section. The felspar constitutes about one-third of the rock.
- 2 Augite in irregular individuals with a maximum length of one millimetre, colourless to pale green—about one-tenth of the rock.
- 3 Hornblende in small brown grains somewhat less abundant than augite.
- 4 Quartz usually large angular grains 35-40 individuals in the section (which is one inch square).
- 5 Chlorite occurs as interstitial material and as a decomposition product of ferro-magnesian minerals (olivine?).
- 6 Biotite occurs sparingly.
- 7 Magnetite.
- 8 Ilmenite altering to—
- 9 Leucoxene.
- 10 Pyrite very sparingly.
11. In addition to the foregoing there are fragments of slate.

"The rock has evidently been derived from a basic or intermediate rock and fragments of quartz and slate have been added. It is not a tuff, for there is no ashy material. It possibly could, however, have been derived from a tuff by a process of natural elutriation."

It will be noticed that this outcrop is bounded on the east by a granite porphyrite complex, on the north and south by rhyolite, and about a mile or so to the west by Brisbane Schists. One hesitates to offer an explanation as to the relationships of this rock to the others in the district, suffice it to state that examples of it occur in numerous places along the andesite granite boundary from SFR 316 to Yarraman railway yard, where it shows jointing, probably due to faulting. It should, perhaps, be considered as part of the porphyrites.

SUMMARY AND CONCLUSIONS

It is customary to give a set of conclusions at the close of a paper such as this, but the writer fears that the facts which he has to offer are too incomplete to suggest any reliable hypotheses which would correlate all the rocks of the district. Even the geological boundaries on the accompanying map are largely interpolated. However, a brief discussion of the rock sequence may prove useful to future workers.

The oldest rocks in South Queensland are the Brisbane Schists, which form a practically continuous block to the east of a line joining Pine Mountain to Kilkivan. An outcrop of this series occurs between Yarraman and Wondai.

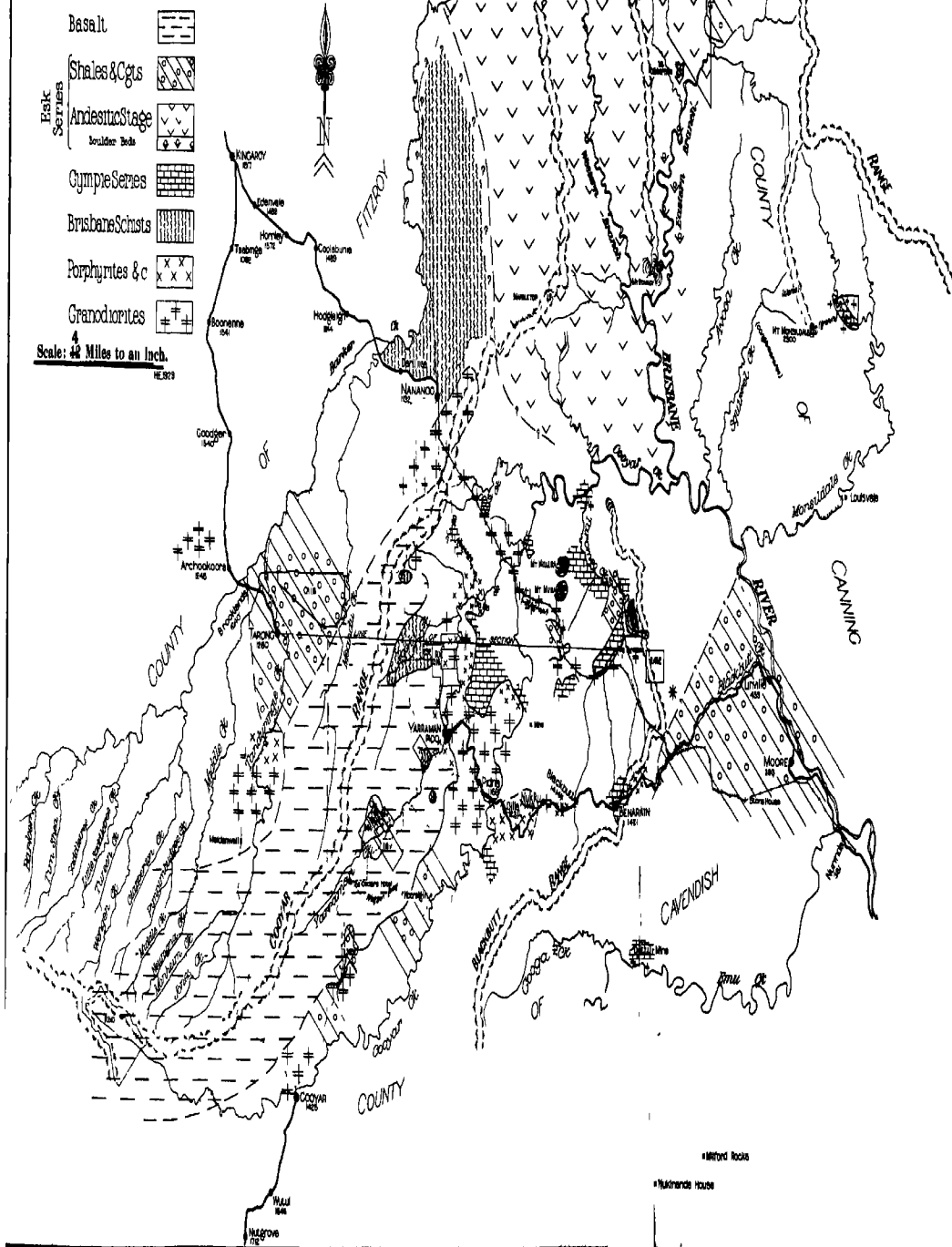
Between Yarraman and Esk there are several outcrops of slates which probably belong to the Gympie Series, whether they are deposited *in situ* or are faulted into their present position is not clear.

The age and meaning of the porphyrite intrusions is not clear, they seem to be older than the granodiorites, and might possibly be related to the massive Esk andesitic stage farther east.

There is doubtless some significance in the fact that the Esk conglomerate beds of the district contain numerous pebbles of milky quartz, jaspers, Brisbane Schist, Gympie Slates, rhyolite, &c., but very few, if any, basic pebbles, with the notable exception of some interbedded greywackes. The conglomerates overlie the granitic intrusions but are overlaid by the (?) Tertiary Cooyar Basalts.

It gives me pleasure to express my gratitude to Miss D. Hill, M.Sc., for references to literature and for helpful criticism, to Dr. W. H. Bryan for encouragement and advice, to Mr. L. C. Ball, B.E., for kind permission to utilise his unpublished sketch-maps of the district, to Mr. A. K. Denmead, M.Sc., for very considerable petrographic and other assistance, to Mr. E. H. F. Swain for his consent to use information from forest surveys, to Mr. F. E. Connah, F.I.C., for the analysis of the coal sample from Por 84v, and to Mr. C. Woods and Mr. H. Everist for aid in drafting the map and section.

GEOLOGICAL SKETCH MAP OF THE LINVILLE-NANANGO DISTRICT



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The Development of the Esk Series between Esk and Linville.

With reference to the Possible Occurrence of Workable Coal

By DOROTHY HILL, M Sc, Research Scholar, University of Queensland.

Two Geological Maps

(Read before the Royal Society of Queensland, 28th April, 1930)

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IX	Summary and Conclusion

I—INTRODUCTION AND ACKNOWLEDGMENTS

This work was carried out by the author while holding the Scholarship for the Encouragement of Original Research of the University of Queensland, field expenses being defrayed by a grant from the Commonwealth Council for Scientific and Industrial Research, the latter being made so that the possibilities of coal in the Brisbane Valley might be explored. The country dealt with extends from Kipper Creek and Bellevue on the south to Avoca Vale and the heads of Sheep Station Creek on the north. The average width is 20 miles, and the length 38 miles, making a total area of 760 square miles. Half of this area (about 380 square miles) has been examined in some detail during the ten weeks' fieldwork, but the other half, on the east of the Brisbane River, has only been touched upon, as may be judged from the few geological data appearing on that half of the map.

The method of working was on horseback from private homes and hotels, one eminently suitable for the district which is closely settled;

while for the outlying Happy Creek area a car camp was arranged, from which the work was again done on horseback

In investigating the possible occurrence of coalfields the following method was adopted —A study was made of the tectonic structures of the area, of which previously little had been known, and, concurrently with this, the lithology of the different types of sediments was examined with a view to determining the conditions of deposition of each. From the knowledge thus gained, localities favourable for the occurrence of coal were deduced. The localities thus determined were then examined in as much detail as time permitted for traces of coal.

These investigations forced one to the conclusion that conditions are distinctly unfavourable for the occurrence of a large field of coal, but it is possible that small occurrences capable of allowing small collieries to supply part of the needs of the Brisbane Valley, including those of the railway line, may be found in some of the synclinal areas. But, apart from this rather negative economic value of the investigations, it is believed that the data collected during the course of the work have more than justified the time and money spent in the field, for they form a very important addition to the knowledge of the tectonic and volcanic geology of our Triassic deposits.

The hospitality and cordiality of the people in the Brisbane Valley made the work very pleasant. In particular I wish to thank Mr and Mrs T J Coleman of Toogoolawah, Mr and Mrs B G White of Moorabool, Mr and Mrs George Graham of Ettawold, Mrs Moore and Miss Moore of Colinton, Mrs J H McConnel and Miss Ursula McConnel of Cressbrook, Miss Gardner of Dingyaira, Mr Marson and Mr Launder of Toogoolawah, and Mr and Mrs R Whyte of Happy Creek. Their generous hospitality and ready assistance made the fieldwork seem like a pleasant holiday amongst friends, and it was with regret that the last field excursion was completed.

Mr C C Morton, of the Geological Survey of Queensland, most kindly made available to me his unpublished reconnaissance maps of the area between Esk and Ottaba, and the Great Moreton Fault Area, while the Rev C H Massey and Dr Bryan have given me dip readings along the main road from Esk to Benarkin. Dr Bryan also read the manuscript and suggested many improvements.

II—PREVIOUS WORK

(A) BIBLIOGRAPHY

In published work on the Brisbane Valley, short references only to the Mesozoic rocks may be found, since the chief object of the reports has been to deal with mineral occurrences in the Palaeozoic rocks.

(1) 1885 C Stutchbury 15th Report, NSW L A Papers, vol 1, p 1185. This describes traverses made from Kilcoy down the valley of the Stanley River, and from Kilcoy west to Colinton, from Colinton through Balfour's (Wallaby) and Jeromeo (Taromeo) Creeks to Bonera.

(Boonara) and Boubyjan Unfortunately this report is not of much assistance owing to the rather indefinite usage of the terms "porphyry" and "trap" and to the difficulty of placing exactly its localities But Stutchbury seems to have been the first to recognise the important felspar porphyry series intruding the Mesozoic Coal Measures

(2) 1892 R L Jack and R Etheridge G S Q P 63, "The Geology and Palaeontology of Queensland and New Guinea" In this the only references to the area under discussion are to "Colinton" and "Kilcoy Range above Crossbrook," both as fossil plant localities

(3) 1901 L C Ball's Annual Report, A R G S for 1900, G S Q P 159 The report has notes on a journey from Esk to Taromeo over the Blackbutt Range, mentioning "trachyte (?) tufts and (?) sheets" in the Mesozoic Coal Measures on Wallaby Creek and on the climb up the range

(4) 1901 C F V Jackson "Mines near Esk," Q G M J, pp 466, 468, 469, and 530 This refers to Palaeozoic rocks only

(5) 1903 W E Cameron "The Dattu Dattu Mine," Q G M J, p 188 This also refers to Palaeozoic rocks only

(6) 1906 L C Ball "The Upper Brisbane Valley," Q G M J, p 470 This contains a short reference to coaly outcrops in the Trias-Jura at the head of Wallaby Creek, and on the Esk-Nanango road

(7) 1912 L C Ball "Mines in the Parish of Taromeo," Q G M J, p 111 Here Trias-Jura rocks are described lying unconformably on Permo-Carboniferous sediments near Taromeo Station

(8) 1912 E O Marks "Prospects of Coal at Esk," Q G M J, p 322 Dr Marks reports unfavourably on certain indications of coal near Esk

(9) 1912 E O Marks "On the Geological Age of South-eastern Queensland Volcanic Rocks," P R S Q, p 139 A Mesozoic age is advocated for certain trachytes near Esk

(10) 1916 H C Richards "Volcanic Rocks of South-eastern Queensland," P R S Q, vol 27, No 7 Places the trachytes above (Marks, 1912 (9)) into the Tertiary

(11) 1918 A B Walkom "The Geology of the Lower Mesozoic Rocks of Queensland," Proc Linn Soc N S W, vol xliii A short reference is here made (p 55) to the belt of rocks between Esk and Cooyar Creek as Walloon

(12) 1923 J H Reid and C C Morton "The Geology of the Country between Esk and Ipswich," Q G M J, p 7 They define the Esk Series from its occurrence south of Esk, as follows —

Esk Series — { Esk Trachytes
 { Esk Shales and Bellevue Conglomerates
 Andesitic Stems

(13) 1926 H C Richards "Volcanic Activity in Queensland," A A A S, 1924, p 285-287 Reid and Morton's (12) placing of the Esk Trachytes as Mesozoic is criticised

(14) 1927 E O Marks "Streams and Their Past," The Queensland Naturalist, vol vi, No 2, pp 28 and 29 Here the Brisbane River and its tributaries are discussed with reference to geological structures possibly determining their courses

(15) 1930 Dorothy Hill "The Stratigraphical Relationship of the Shales about Esk to the Sediments of the Ipswich Basin," P R S Q, vol xli, p 162 The Esk Series is redefined for the area south of Esk, as follows —

Esk Series —	{	Esk Shales — Bellevue Conglomerates — Basal Ipswich Conglomerates Acid Tuff Stage = Brisbane Tuff Andesitic Boulder Beds
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(B) UNPUBLISHED WORK

In addition to the above, Mr C C Morton did some preliminary mapping in the area between Esk and Otteba, and along the Great Moreton Fault Area, and kindly made available to me his data. Rev C H Massey and Dr W H Bryan have given me notes of outcrops along the main road from Esk to Benarkin, and Mr E C Tommerup has prepared for publication a paper on the country at the heads of the Brisbane River, to the north and north-west of Linville

III — PHYSIOGRAPHY

Physiographically the area shown on the map consists of a long trough of Triassic sediments set in higher walls of Palæozoic rocks. In the western wall, head a number of streams which run to the centre of the Mesozoic trough as the western tributaries of the Brisbane River, which flows in a series of short meanders in a general south-easterly direction about the axis of the trough. The general direction of these tributaries is north-easterly, at right angles to the strike of both Palæozoic and Triassic deposits. Those streams heading in the eastern Palæozoic highlands have a general westerly course, and run into the Stanley River and the Brisbane River below its confluence with the Stanley, which flows southerly close against the eastern faulted junction of Triassic and Palæozoic. While in the schists, however, the Stanley follows a westerly course.

The general direction of the Brisbane River is a straight north-westerly line with meanders of short radius to either side. From Avoca Creek to south of Moorabool the position of the river has been determined by the Colinton axis of disturbance,* and possibly also by the Neera Creek Disturbance. The junction of the Upper and Lower Esk Series closely follows the course of the river.

The northern part of the Eastern Border Fault is responsible for the course of Sheep Station Creek.

* Marks, 1927. The Qld Naturalist, vol. vi, No 2, pp 28, 29

The divide between the Brisbane and the Stanley is formed by the Toogoolawah mountains (Kilcoy Range) rising to over 2,000 ft.; i.e., it is higher than the highlands of the schist walls. This height of Triassic sediments is due to their intense hardening by intrusions of felspar-hornblende, porphyry, and granodiorite along a line of disturbance. So sudden is the rise to the range from the surrounding country that erosion at the heads of streams has cut high canyon walls (e.g., Black Jack's Creek), while one mile downstream the same creek meanders about in its own alluvial plains. There are many unscalable cliffs on the eastern side of the range also. The streams running into the Brisbane River have a general south-westerly course, while those running into the Stanley flow easterly. This divide is much closer to the Stanley than to the Brisbane, so that the former is confined on both sides, and in its lower course has had to cut its way through rhyolite and a large granodiorite intrusion, forming the well-known Stanley Gorge. This is in strong contrast to the Brisbane River, which has great wide alluvial flood-plains.

The important topographical units are thus three —

- (1) The bordering highlands of Palæozoic rocks,
- (2) The basin of Triassic rocks, with its unsymmetrically placed backbone,
- (3) The Toogoolawah mountains (Brisbane-Stanley Divide)

When the streams head in the Palæozoic rocks, their feeding gullies are V-shaped, steeply inclined, and of varying heights, while the tops of the ridges on which they are cut are approximately equal in height (which might perhaps be regarded as evidence of a pre Mesozoic erosion level). The streams themselves in the schists have rocky banks, or narrow flood-plains built up of angular pebbles, but when they flow down on to the Triassics they have wide alluvial flood-plains of black soil, in which they are constantly changing their courses. The great flood-plain of Crossbrook Creek is one of the most noticeable of the topographic features. It is wider than that of the Brisbane River itself.

Thus the normal erosion of the Triassic rocks is a mature type, but, when they have been hardened by intrusion, youthful forms result (as seen in the Toogoolawah mountains). A line of hills, the Moore-Harlin ridges, runs NW to SE close to the western banks of the Brisbane River, crossing the river and running east at Harlin as the Staghurst Range to join the Toogoolawah mountains, and this line shows topography characteristic of steeply dipping differentially hardened basin sediments. A similar line of ridges runs from Ivory's Creek through Toogoolawah and Ottab.

A second type of highland in the Triassics is due to the differential hardness of the unintruded sediments when trachytes are interbedded. The latter weather into long ridges when the dip is pronounced, and into flat-topped hills when the dip is negligible. Thus the rough country forming the foothills to the Blackbutt Range and the high banks of the

Brisbane River at Wheeler's Crossing are due to trachytes interbedded in sediments with rapidly changing dips, while the ranges about Coal Creek settlement owe their altitude to the capping of gently dipping Triassic trachyte.

The topography on the east of the river north and north-west of the Staghuist Range is most striking but monotonous. It consists of spherical, conical, or elliptical humps rising with arcuate (convex) profiles out of U-shaped gullies. They reach no great height above these gullies (80-100 ft.), but then convex profiles give them a forbidding steepness. They form excellent grazing country. This is the Andesitic Boulder Bed type of topography, and is persistent from Gregor's Creek to Monsildale Creek. Where it is hardened by intrusion, only the size of the hump is exaggerated.

Tertiary intrusions into flattish Triassic trachytes account for the great Mount Esk mass overlooking Esk from the east: a Tertiary rhyolite flow for the steep hill opposite Ottaba station, while a development of fluidal rhyolite forms the divide between the Crossbrook and Burraba waters.

The Bundamba sandstone in the south weathers to characteristic mild 'Hawkesbury' forms, due to the massive nature and gentle dips. It is rich in springs.

The whole of the trough of Mesozoic sediments forms excellent well-watered grazing and dairying country, while the value of the western wall of Palaeozoic rocks lies mainly in its timber content. It is not well watered, and is much rougher than the country in the trough, and consequently is of much less value.

IV —TECTONIC STRUCTURE

The Esk Series (of Triassic age) between Esk and Linville has been trough-faulted into Palaeozoic rocks along lines parallel to the geological grain of South-eastern Queensland—i.e., north-west. The Esk Series in the trough may be divided into two conformable units—the Upper Esk Series,* including the northern representatives of both Acid Tuff Stage† and Esk shales, and the Lower Esk Series (Andesitic Stage or Andesitic Boulder Beds). The distribution of the Upper and Lower Esk Series in the trough is remarkable. The Lower Esk Series is entirely confined to the north-eastern half of the trough, and the Upper Esk (with the exception of certain (†) faulted blocks in the Toogoolawah mountains) to the south-western. The reason for this distribution is not yet understood. Tilting of the Esk Series to the west before the trough faulting seems the most likely of the many explanations offering

* The combination of the Esk shales and Acid Tuff Stage into the Upper Esk Series is desirable in this paper because the work has not been detailed enough to sort out the northern equivalents of these two stages, and for the sake of uniformity the Andesitic Boulder Beds are here referred to as the Lower Esk Series.

† Proc. Roy. Soc. Qld., vol. xii, 1930, p. 169.

The most striking tectonic features of the trough are three axes of disturbance—the Ottaba axis, the Colinton axis, and the Toogoolawah mountains disturbance. All three are represented by topographic highlands. The first two of these are very sharp, fractured anticlines accompanied by intrusions along the line of disturbance, and the third will probably prove to be similar. Between these axes and the margins of the trough there are gentle synclinal structures. A development of Bundamba sandstone overlies with apparent conformity the most southerly development of the Upper Esk Series in this area, both being involved in the Western Border faulting.

At present there is no evidence to show whether the trough-faulting dropping down the Triassic sediments into the Palaeozoic rocks occurred before, after, or contemporaneously with the folding and faulting within the trough. The Ottaba anticlinal fracturing took place before the extension of the Ottaba Tertiary rhyolite, and the marginal faulting occurred before the extrusion of the Ettswold Tertiary rhyolites and after the deposition of the Bundamba sandstone.

(A) MARGINAL FAULTING

(a) Western Border Fault* System and Associated Palaeozoic Rocks

This system covers the number of intersecting faults forming the western boundary of the Esk Series, with downthrow always towards the east. At Pryde's Pinch, Bundamba sandstones are downfaulted against pyritised (?) Permo-Carboniferous cherts and tuffs, but on the Kipper Divide the fault is overlapped by the Tertiary Ettswold rhyolite. North of the outcrop of this overlapping rhyolite, at Cressbrook Creek, the downthrow side of the fault (which there runs N N E) is occupied by vertical Upper Esk conglomerates and trachytes. These are faulted against compact blue fossiliferous calcareous sediments and felspar porphyries of undoubted Permo-Carboniferous age, which strike N W and dip steeply (75°) to S W. Locality A (see Map) yields *Monilopora*, *Trachypora*, and *Lophrentis*, and Locality B *Monilopora*, *Mourlonia*, and *Conularia*, with B believed to be lower than A. The effects of this fault are distinctly visible for half a mile, but then the dips rapidly flatten to the normal horizontal position.

On the Esk-Biarra road the Upper Esk Series is downfaulted against old Palaeozoic rocks probably equivalent to the Fernvale Series of the Brisbane Schists, and a long ridge of hard compact Upper Esk conglomerate runs parallel to the fault from the road to Cressbrook Creek. North of Cressbrook Creek, almost to Ivory's Creek, the rectilinear nature of the trough boundary is missing, and the alluvial plains of Cressbrook Creek run up to pink (Eskdale) granite intruded by blue diorites and a fine andesite, the junction being an irregularly rounded one. Just south of Ivory's Creek, however, the vertical Upper Esk

* This and the other structural names introduced in this and the following sections are now used for the first time, and have been chosen with regard to the localities in which they are typically developed.

conglomerates are again seen, and here they are downfaulted against weathered andesites, bluish cherts, and (?) rhyolites with a strike E of N, intruded by a grey biotitic granite and a blue diorite (fine-grained), followed to the west by the red quartzites of the (?) Fernvale Series. The fault runs N by W almost to Maronghi Creek, the vertical conglomerates lying against the red (?) Fernvale quartzites. From near Maronghi Creek a fault runs N W to the Ironside Creek dam, where a fault coming in from the west steps out the western boundary of the Triassics about 3 miles to the west. This east-west fault may be called Ironside Fault, and appears to have some difference in downthrow from the Maronghi Creek-Happy Creek fault, for trachytes are not visible in the steeply tilted strata of the latter, while they are very obvious in the moderately dipping strata of the former.

The Palaeozoic rocks west of Happy Creek and to the south of Ironside Creek are a series of vesicular andesites, slates, bluish cherts, and coarse grits, intruded by blue dioritic rocks, with an average strike of N 30° W, and steep dips in both directions. Small quantities of gold are being obtained by washing from the various creeks on this development of Palaeozoic rocks. The fault crossing the railway line near Benarkin runs N N W and separates vertical Upper Esk conglomerates from granite, but on the Moore-Benarkin road the Palaeozoic outcrops are obscured by a deep red laterite.

(b) *The Great Moreton or Eastern Border Fault System*

The author has not touched upon this area in the field, except at Kilcoy, and is therefore much indebted to Mr. Morton, who has kindly given permission to use his unpublished mapping of the fault in this map. The several members of the Brisbane Schist Formation against which the Triassic rocks are downfaulted may be found in Mr. A. K. Denmead's "A Survey of the Brisbane Schist".*

(B) CENTRAL FAULTING AND FOLDING

(a) *Bundamba Folding*

Little is known of this wherever dips were taken along Redbank Creek, the Bundamba sandstone appeared flat, except at its most easterly outcrop, where it was involved in the south-westerly dip of the Esk Series of the type area, and had a dip of 5° S W, and at its most westerly outcrop where it was dipping slightly east due to the effects of the Western Border Fault. From the mapping, one suspects it of being a long monoclinial fold dipping S W, tilted easterly just at its western edge by the influence of the Western Border Fault.

(b) *The Ottaba Axis of Anticlinal Fracturing and Intrusion*

This is a most important structural line. Its structural and topographic effects are to be seen in the long line of ridges from Ivory's Creek south-easterly through Toogoolawah and Ottaba to the head of Coal Creek. It may be continued to the south-east as the augite andesite

intrusions which are partly responsible for the weather-resisting mass of Mount Esk. North of Ivory's Creek its effects have not been distinguished from those of the western border faulting, and it may be that a continuation caused the Stone House Disturbance. From Ivory's Creek to Toogoolawah it forms a belt over a mile in width of sharp anticlinal uparching and fracture, the sediments being vertical or steeply dipping. In one place only (Por 136 par Biarra) is the accompanying intrusion visible. From Toogoolawah to Ottaba only the gently dipping eastern limb of the anticline may be seen rising out of the Cressbrook Creek flood-plains, but at Ottaba the area of disturbance broadens. Here it is accompanied by igneous intrusion divisible into three groups: (1) the eastern hornblende felspar porphyrite intrusions of Mount Beppo, (2) the augite andesite intrusions of Ottaba, and (3) the augite andesite intrusions of Por 28v par Biarra, the last being overlaid unconformably by a Tertiary rhyolite flow. The sudden intensity of igneous effects at Ottaba has its analogue in the effects around Moorabool of the Colinton line or axis of movement.

(c) *The Stone House Disturbance*

It will be observed that there has been a sudden steepening of dips to the north-east at the Stone House on Wallaby Creek, and again, north-west of this, in the Lanville-Benarkin railway line. It is probable that these effects are due to the prolongation of the conjoined lines of disturbance of the Ottaba axis of disturbance and the Maronghi-Happy Creek fault.

(d) *The Coal Creek Syncline*

South of Mount Esk, the Esk sediments are disposed in a gentle monocline dipping S.W. To the north of Mount Esk, however, a gentle syncline is formed between the Ottaba fractured anticline and this monocline. This structure may be termed the Coal Creek syncline, and is well shown topographically, due to the hardness of the interbedded trachytes. It is covered to the north by the alluvial plains of Cressbrook Creek.

(e) *The Glen Harding Syncline, the Maronghi Centrally Arched Syncline, and the Wallaby Syncline*

North of Yimbun, synclines are again seen east of the Ottaba fractured anticline, but here their eastern limb forms the western limb of the Colinton fractured anticline. Between Ivory's Creek and Maronghi Creek the syncline is a simple one, between Maronghi Creek and Emu Creek it has a central anticline, and north of Happy Creek there is a long syncline running between the uparched strata of the Stone House Disturbance and the Colinton anticline, to be called the Wallaby syncline. These three synclines are obvious from the topography, due to the differential hardness of beds of sandstone and compact conglomerate as compared with shales and more loosely bedded conglomerates.

(f) *The Colinton Axis of Anticlinal Fracturing and Intrusion*

The strata affected by this N.W.-S.E. disturbance may be seen from its east of Yimbun running north-west through Harlin, Colinton,

Moore, and Linville to Avoca Creek From Yumbun north-east to Por. 124v par Neara, there is a three-mile-wide belt of what was once a gentle monocline dipping 3° S W and exposing to the east the Andesitic Boulder Beds This has been cut through by at least two lines of sharp anticlinal fracturing with the concomitant intrusion of many sheets of coarse felspar-hornblende porphyry These are concordant in the steeply arched strata and slightly transgressive in those which are only gently folded The more westerly of these lines, seen in the Yumbun railway cuttings, is the southern end of the Colinton axis, and the more easterly may be called the Neara Creek fracture line The Colinton line continues north-west as a disturbed anticlinal belt about $1\frac{1}{2}$ mile wide, similar to the Ottaba line Core like intrusions are seen (Section VII (b)) near Nulunda station, at Colinton and near Linville Where the intrusions are not obvious, much fracturing with steep dips to either side may be seen across the belt, e.g. in the road between Hailin and Colinton, and between Colinton and Moore The road between Moore and Avoca Creek seems from the constant steep N E dip to pass along the steep eastern limb of the antiform This is the case as seen in the railway cuttings near Linville It may reasonably be assumed to be the structure north of Linville

(g) *The Neara Creek Fracture Line*

This is the more easterly of the two fracture lines mentioned in the last paragraph Its effects are seen in outcrops of vertical conglomerates and shales baked by the contemporaneous intrusion of coarse sill-like felspar porphyry in the ridges in Pors 86, 88, '9 par Neara, and north-west along the river to Neara Creek These effects die out rapidly eastwards, and in Por. 124v par Neara slight dips of 33° S W are noted in the basal Gregor's Creek syncline, in which are intruded sills of felspar porphyry and augite andesite the latter forming cliffs The Neara Creek fracture line appears to be prolonged to the south to Por. 117 par Cressbrook, causing a local dip of 60° N E in the otherwise gently dipping sediments

North-west at Avoca Creek soft shales and conglomerates of the Upper Esk Series dipping at 80° N E are seen on one side of the river, whereas intensely hardened andesitic boulder beds outcrop on the other, apparently dipping moderately N E Again, on the Arrababy Creek road, one-quarter of a mile from the river, Upper Esk conglomerates dipping 60° N E are separated from the Lower Esk andesitic boulder beds by only about 50 yards of alluvium Relations here may prove to be the same as those in Pors 87 and 124v par Neara, but the possibility of a fault along the river bed here must not be overlooked The Neara Creek Disturbance is also probably continuous to the south-east of Moorabool

(h) *The Toogoolawah Mountains Disturbance*

At the heads of Scrub and Black Jack's Creeks are seen hardened Upper Esk sediments conformably overlying hardened andesitic boulder beds, all being tilted at 80° to the north-east Farther west, at the river,

the dips were slight to the south-west. Consequently some faulting or folding has occurred between these two places. The intrusions of hornblende felspar porphyry, seen in these Upper Esk sediments from the heads of Scrub Creek south-east to Mount Goonnerringgiringi probably accompanied this disturbance. At the "K C B tree," a noted survey mark, a great intrusion of a fine granular rock occurs, forming the Goonnerringgiringi cliffs, and south-easterly from Goonnerringgiringi the important Mount Brisbane granodiorite outcrops.

Thus the evidence shows that disturbance on a large scale has occurred in the Toogoolawah mountains, but the data are not sufficient to define its nature. It is probably the most important of all the disturbances affecting the Triassic sediments in the trough.

V—THE UPPER ESK SERIES

The Upper Esk Series is a series of basin sediments and volcanic rocks which occupies that half of the Brisbane Valley Trough to the south-west of the diagonally flowing Brisbane River, and which lies between the Lower Esk Series or Andesitic Boulder Beds and the Bundamba sandstone. It therefore includes the Esk shales and the Acid Tuff Stage*. It has been sharply folded about two north-west axes of anticlinal fracturing and tilted by the Western Border Fault. These movements, whose effects are the most spectacular attributes of the Upper Esk Series, have been treated in Section IV. The series has been intruded along the two lines of anticlinal fracturing by representatives of the Brisbane Valley Porphyrite Series† with hardening and freshening of the sediments and volcanics along the central zone.

An outlier or fault block of Upper Esk Series occurs in the Toogoolawah mountains, running from the heads of Scrub and Black Jack's Creeks along the range south-east to Mount Goonnerringgiringi. It consists of massive conglomerates, grits, and shales, usually intensely hardened by the numerous intrusions of felspar hornblende porphyry, dipping steeply (80° to 45°) N E, and conformably underlain to the west by the Andesitic Boulder Beds.

The Upper Esk Series lies conformably on the Lower Esk Series of andesitic boulder beds, as may be seen along the junction from Paddy Gully to Nears Creek. The best locality for studying this conformity is on Gregor's Creek, where the rocks at the junction are baked hard and massive (Por 124v par Nears). Here boulders consisting of the porphyritic andesite of the true boulder beds are set in a matrix which is elastic, instead of laval or tuffaceous as in the true andesitic boulder beds. This denotes the beginning of the permanent change from the conditions necessary for the formation of the peculiar andesitic boulder beds, to the action of ordinary sedimentary processes, and this point of

(f) Footnote p 38

Section VII (C)

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change is the point of division between the Upper and Lower Esk Series, and the two are thus closely related. For both are the result of interacting volcanic and sedimentary processes, and while the Lower Esk might be referred to as the Andesitic stage,* the Upper Esk Series might be called the Trachytic stage. In the former volcanic activity was predominant over sedimentation, but in the latter sedimentation was predominant over volcanic activity, and almost to the same degree. In the south, at Paddy Gully, the change from Lower to Upper Esk is seen in trachyte flows and tuffs overlying the Andesitic Boulder Beds.

Relations between the Andesitic Boulder Beds and the Upper Esk Series at Avoca and Arribaby Creeks suggest a faulted junction, perhaps owing to lack of data, and more work may show relations like those of the Neara Creek fracture line †. In the south-western part of the area, the Upper Esk Series is overlaid by the massive current-bedded brown siliceous Bundamba Sandstones. The junction on the west at Cressbrook Creek shows angular conformity, but Messrs. Reid and Morton ‡ consider that on the east there is a slight angular unconformity. The Bundamba Sandstone was deposited before the Western Border Faulting, and probably also before the anticlinal fracturing and intrusion.

The volcanic rocks interbedded with the basin sediments of the Upper Esk Series are biscuit-coloured trachytes and trachyte tuffs, with an occasional andesite. They are to be seen best developed in the north-west and south-east corners of the Upper Esk Series. In the south-east corner three flows are to be seen in the Coal Creek syncline, their tuffaceous representatives outcropping in the Paddy Gully monocline. In the north-western corner many trachyte flows and a few andesites and tuffs may be seen interbedded with the gently dipping massive conglomerates and grits on Wallaby Creek and just to the north of the Ironside Fault. Many smaller outcrops (to be seen on the map) occur throughout the series. These localities are given in the section on Igneous Activity.

The basin sediments found are dark-green conglomerates and grits, olive-green shales, and some carbonaceous seams. The conglomerates have pebbles of from 1 to 4 in. in diameter, set usually in a fairly coarse matrix, which, like the grits, consists largely of fresh mineral fragments. The shales are very fine, sometimes colour banded, and where readily fissile usually rich in fossil plants of the typical Upper Esk facies. A wonderful locality for fossil plants is the "Rock Pool" in Happy Creek, just below the Ironside dam, and nearly all the genera and species characteristic of the Upper Esk Series, with some undescribed forms, occur here in abundance. Where freshened by intrusion, the conglomerates show a composite blue colour on unweathered surfaces. Whether the greenish colour of the unaltered sediments is primarily due to climatological factors during deposition or to the type of rocks from which the sediments were derived is a problem not yet investigated.

* Reid and Morton, 1923, p. 9

† See Section IV (B) (f)

‡ Loc. cit. p. 16

The investigation of the lateral lithological variations in these basin sediments was too detailed an undertaking for the present reconnaissance. It is fortunate, for future studies, that igneous activity recurred at short intervals during the Upper Esk sedimentation, for by tracing these fixed horizons continuously from east to west and from south to north (a matter of some difficulty and interest owing to the axes of sharp folding and fracturing) the sedimentary variations may be chronologically examined and locality-time-tables drawn up showing the temporal and spatial distribution of the lithological types. From these and from data such as current bedding, elongation of pebbles, lateral variation in size, and in percentage of lithological types of pebbles, it should be possible to determine the direction of currents in the basin, the position of shore lines and feeding rivers, and perhaps also movements affecting the basin during deposition.

The Paddy Gully section seems to be anomalous in the fineness of the sediments and the thickness of the Upper Esk Series, for elsewhere it is of much greater thickness and of much coarser grain. The possibility of Bundamba overlap is regarded as worth investigation.

VI—THE LOWER ESK SERIES

The Lower Esk Series, Andesitic Stage or Andesitic Boulder Beds, occupies that part of the Brisbane Valley Trough east of the Brisbane River, and is known to continue north-west to Boonara, a distance of over 100 miles. Why it outcrops no farther south than the Mount Brisbane area is not yet known. Its thickness has not been ascertained, but must be calculable in thousands of feet.

Little is yet known of the movements affecting this series beyond the facts (1) that it dips gently and conformably under the Upper Esk Series to the south west, (2) that it is sharply uptilted at its eastern faulted junction with the Brisbane Schists, and (3) that some disturbance in the Toogoolawah mountains accounts for an outlier of steeply tilted Upper Esk Series. It is known to have been intruded by the Brisbane Valley Porphyrites near Avoca Vale, on Gregor's Creek, and in the Toogoolawah mountains, and in these places the matrix of the boulder beds is very hard and fresh.

Andesitic boulder beds make up by far the greatest bulk of the Lower Esk Series hence the retention of the name Andesitic Boulder Beds to emphasize the peculiarity of the stage as compared with an ordinary "andesitic stage". The boulders of the boulder beds are always of porphyritic andesite, and the beds containing them may be divided into types according to their matrix. The first type is one in which the matrix is itself an andesitic flow, and the boulders included are usually very large and round. The second type is one in which the matrix is a tuff and the boulders here are of different sizes and are very angular. In a third type the matrix is partly tuffaceous and partly st. clastic, and the fourth type is a true conglomerate, with its just as

matrix consisting of clastic grains, its boulders rounded and not all of porphyritic andesite. Such a conglomerate outcrops along the road to Kileoy at Por 50v par Kileoy. Interbedded with the boulder beds are seen andesitic tuffs (in one of which *Nilssonia cf. princeps** has been found), andesite flows, rhyolite flows, rhyolite tuffs, tuffaceous grits and shales the latter often containing plant remains. Thus the Andesitic Boulder Beds were laid down under water, so that in between the periods of volcanic activity short periods of ordinary sedimentary deposition occurred.

Many things remain to be explained regarding this series, e.g.—(1) How did such a tremendous extent of porphyritic andesite come to be broken up into countless millions of boulders of all sizes and shapes and deposited in various matrices in the Triassic Basin? (2) Why does the series not appear south of Mount Brisbane? (3) Why does it not appear on the western side of the trough? (4) What is the relation of the chemical composition of the porphyritic andesite to the Brisbane Valley Porphyrites, the Upper Esk Trachytes, the Permian-Carboniferous volcanics, and the Tertiary volcanics? The study of the lateral lithological variation of the Lower Esk Series would be no less interesting than that of the Upper Esk Series.

VII IGNEOUS ACTIVITY

Igneous activity occurred in the down-faulted area four times since the beginning of sedimentation in the basin. The earliest is the andesitic activity to which the deposition of the Lower Esk Series is due, the second is the trachytic activity during the deposition of the Upper Esk Series, the third is the intrusion of the Brisbane Valley Porphyrites while the central folding and faulting was in progress, and the fourth the Tertiary rhyolitic activity. No chemical or microscopical examinations of the rocks have been made during this work, so that the chemical and mineralogical interrelations of the various phases cannot be properly discussed and in the sections which follow, the conclusions drawn have been based on macroscopic examinations of hand specimens only. One fact is obvious, however, and it is that the parent magmas of the Andesitic Stage, the Trachytic Stage, and the Brisbane Valley Porphyrites were of an intermediate type and it may reasonably be inferred that they are closely related one to another. Indeed it may be that the one parent magma was drawn on during all three periods of activity.

(A) ANDESITIC BOULDER BEDS

The boulders of the Andesitic Boulder Beds have been derived from a tremendous quantity of porphyritic andesite, the product of some very extensive igneous activity, probably volcanic. The similarity of type of these boulders over the whole of the area is remarkable, and a general description will cover them all—Cream or sometimes flesh-coloured felspars, usually lath-shaped and of varying sizes, with some-

* Verbal communication, W. H. Bryan

times a few needle-shaped hornblendes fairly closely set as phenocrysts in a very fine-grained or glassy matrix, the colour of which varies from red through intermediate shades to bluey-grey or green. The boulders vary in size from 2 in in diameter to as long as 4 ft, while the commonest sizes are 4 in and 1 ft

Where the matrix of the boulders is a flow this flow is also a porphyritic andesite, and its greenish matrix has phenocrysts of creamy felspar which are rather stouter than those of the boulders, and tend to be arranged with their longer axes parallel, giving a fluxion structure. Where the matrix is tuffaceous it is generally very weathered, but well shaped felspars may usually be distinguished in it.

The author has not seen any interbedded andesite flows, but andesitic tuffs are very common. In the Toogoolawah mountains, along Macphail's branch of Black Jack's Creek, two steeply dipping developments of *banded rhyolites* are to be seen interbedded with the boulder beds. Glassy phenocrysts of orthoclase may be distinguished in their grey, waxy matrix. The lower rhyolite is accompanied by a tuff.

As to the age of this volcanic activity, it is later than the movement folding the Permo-Carboniferous beds of Crossbrook Creek and earlier than the Upper Esk Series (of Keuper* age), for it lies conformably below the Upper Esk Series, and the latter is downfaulted against the folded Crossbrook Creek Permo Carboniferous.

(B) ACID TUFF STAGE

The volcanic rocks of this division consist of a number of trachyte flows and tuffs with an occasional andesite interbedded with the basin sediments of the Upper Esk Series. The flows are biscuit-coloured, due to the limonitic nature of the fine, powdery, rather weathered matrix. Set in this matrix are rather sparsely distributed phenocrysts of lath-shaped or tabular creamy felspars and usually long limonitic patches showing the position of phenocrysts of needle-shaped hornblende, in fresher rocks the unweathered hornblende needles may be seen, and the matrix is then a light-brown colour. Nests of calcite are occasionally seen.

This description applies to all three of the Coal Creek syncline flows and to all those seen on Wallaby Creek and north of the Ironside fault. It also applies to trachytes seen in the Ottaba ridge, to the flow in Por 42v par Biarria, to that in Por 64 par Esk, to those in Por 51 par. Esk, and to parts of the Esk trachyte†. Probable trachytes of a grey colour are seen in Por 139 par Biarria, and in Por 71A par. Colinton.

* Proc Roy Soc Qld 1930, vol xli, p 186

† This term, by reason of a controversy as to its age and origin (see P B S Q 1930, vol xli, p 173), applies to the trachyte a mile west of Esk. Interbedded sand tuffs of the Upper Esk Series are seen just to the west of the "Esk trachyte," but their relation to the "Esk trachyte" is not known. If the "Esk trachyte" could be proved to be a flow, as seems likely, then the Esk shales as defined by the (f) must be regarded as a subdivision of her Acid Tuff Stage, which would then be synonymous with the "Upper Esk Series."

The tuffs associated with these trachytes are also biscuit-coloured, usually fine in grain, but often consisting of fairly coarse angular fragments in a finer matrix, e.g. those associated with the middle trachyte of the Coal Creek syncline, the tuffs of Paddy Gully, those in Por 30 par Esk, and those associated with trachytes in the Ottaba ridge. Coarse acid tuffs are interbedded with the steeply dipping conglomerates in the Yimbun railway cuttings, and in the gently dipping Upper Esk or Neara Creek. Fine-grained tuffs are associated with a very weathered trachyte flow on the northern boundary of Por 18 par Biarra. Trachyte tuffs are not common in the Wallaby Creek beds.

Andesite flows in the Upper Esk Series are occasionally seen. They usually show needle-shaped phenocrysts of a glassy felspar and hornblende in a fine grey-green matrix, e.g. Paddy Gully andesite, but those on Wallaby Creek take on a different texture, glassy rounded felspars in an iron-grey matrix. Chiffs of an (?) augite andesite conformable with the bedding of the Upper Esk shales are seen on Gregor's Creek (Por 124v), but this development is possibly intrusive.

(C) THE BRISBANE VALLEY PORPHYRITES

This is the name proposed for an important series of intrusive rocks discovered piercing the Esk Series along lines of anticlinal fracturing in the Brisbane Valley. The intrusions are all porphyritic in texture and intermediate in chemical type, and have not been responsible for any mineralisation of the injected sediments. They are all distinctly related to one another, and the following general description covers any one of them.—Abundant large phenocrysts of felspar and hornblende set in a fine-grained grey matrix. Nevertheless for purposes of more detailed description they can be divided into several sub-classes, and these, with the localities in which they are to be found and the nature of the intrusion, are seen below.—

(a) The felspar and hornblende phenocrysts are present in about equal proportions—

(1) The rocks are truly porphyritic. This type is seen in the Mount Beppo intrusions and in Pors 81 and 82 par Cressbrook, Moreton (Toogoolawah mountains). These intrusions are transgressive.

(11) The rocks are nearly equigranular, due to the very small development of matrix. This type is seen in the slightly transgressive intrusions of Moorabool and the Sugarloaf paddock.

(b) The felspar phenocrysts are very large, and very few and small hornblendes are present—

(1) The felspars are stout. These are seen in the slightly transgressive sheets of Gregor's Creek (pink felspar) and the sills of the Yimbun railway cutting and Neara Creek.

- (11) The felspars are tabular, twinned along the narrow axis. These are seen in the core-like intrusion at Nurinda and Colinton. Associated with it at Nurinda is a beautiful green mottled rock, the spots consisting of radiating lath-shaped crystals of felspar and hornblende.
- (c) Large phenocrysts of hornblende are developed almost to the exclusion of felspar phenocrysts. The hornblendes are idiomorphic with beautifully developed faces, and all are complete crystals, neither fractured nor corroded. This type occurs in Por 1 par Biaria.
- (d) Small idiomorphic hornblendes and large white felspars form a spotted rock. No groundmass is present. This is the intrusion which forms the Gooneringgiringi cliffs.
- (e) Instead of hornblende, the ferro-magnesian phenocrysts are augite, and the felspars are small. These are the Ottaba augite andesites described by Richards.*

This Brisbane Valley Porphyritic series is quite new, and opens a very interesting field of study to the petrologist. The Mount Brisbane granodiorite and related intrusions are in all probability part of it. The Porphyrites were intruded before the extrusion of the Tertiary Ottaba rhyolite, for the latter lies unconformably on Upper Esk sediments intruded by the Ottaba augite andesites. A coarse-grained intrusion of felspar and hornblende rock lies between the Upper Esk Series and the Bundamba sandstones on Paddy Gully. If, as seems likely, this sill can be shown to belong to the Brisbane Valley Porphyrites, the date of intrusion of the latter could be fixed as post-Bundamba.

(D) MISCELLANEOUS IGNEOUS ROCKS

The Ottaba and Glen Rock Tertiary rhyolites have both been described by Dr. Richards†. A third development of Tertiary rhyolite is seen on the Kipper and Crossbrook and Buaraba divides, and is a northern finger from the Buaraba rhyolites reported on by Mr. Reid‡. Heavy developments of rhyolites of unknown relations are seen in the Stanley Gorge and east of the Brisbane River at Mullumba. A basalt overlies the tilted Upper Esk Series at Biaria, and a fine-grained andesite occurs in Por 31v par Biaria.

Brief Notes on the Occurrence of Igneous Rocks in the Palaeozoic along the Western Boundary of the Trough

A considerable development of a light-coloured quartz porphyry occurs associated with the fossiliferous beds of Permian-Carboniferous age at Crossbrook Creek. Its relationships have not been ascertained.

Very compact andesitic and (?) spilitic rocks form a considerable

con-

* Proc Roy Soc Qld 1916, vol 27, p 159

(†) Proc Roy Soc Qld 1916, vol 27, p 139

The st. 1923, Qld Govt Min Jnl p 463

part of the (?) Devonian basement in the upper part of the Cressbrook Creek area. Weathered (?) Devonian andesites are seen in Por 30v par Biarra.

A pink quartzitic granite is seen north of Sandy Gully school, associated with a fine grained andesite with small glassy phenocrysts of felspar.

In Por 112 an augite diorite is intruded by a similar andesite, and in Por 114 the augite diorite intrudes a grey biotitic granite (like the Eskdale granite). This grey granite intrudes in its turn the weathered andesites interbedded with the Fernvale jaspers in Por 114.

On Happy Creek (?) Devonian vesicular andesites occur, and this series is intruded farther to the west by a fine andesite.

VIII - POSSIBLE PRESENCE OF COALFIELDS

Of the Mesozoic formations of the Brisbane Valley between Esk and Linville, only the Upper Esk Series might be regarded as having been deposited under conditions favourable to the formation of coal. This important conclusion was reached for the following reasons —

- 1 The Lower Esk Series is almost entirely volcanic.
- 2 The small area of Bundamba sandstone is, as in the Ipswich field, quite barren.
- 3 No equivalent of the Ipswich coal measures occurs here between the Upper Esk Series (or Basal Ipswich conglomerate) and the Bundamba sandstone.

The work done in the area shows that the chance of finding payable coal is still further restricted by the following considerations —

- 1 The closeness of the lines of sharp anticlinal fracturing and intrusion leaves little space between for the extensive occurrence of flat-lying seams.
- 2 The rapid fluctuation in the conditions governing sedimentation in the basin, as shown by the rapid alternation and lateral change of coarse conglomerates, grits, and shales, has precluded any continuously extensive coal horizons being formed.

There is a possibility, however, that synclinal areas may have in some places coincided with a part of the original basin where the conditions of deposition were favourable to the formation of coal. If such could be found, then there would be an opening for a small colliery or collieries to supply the industries of the Brisbane Valley. A map has been drawn up to show the probable extent of coal in those localities where coal has been found to outcrop. The localities are numbered as in the descriptions below.

(A) The existence of coal in small quantities had been reported from the following localities before the work was undertaken.—

- (1) A carbonaceous seam just outside the town of Esk in a well in Por 33 par Esk had been reported on by Dr E O Marks* as not large enough to be remunerative to work. It occurs in a gentle monocline, and the area is thus structurally suitable, but judging from the outcrops this monocline is not promising.
- (2) In the same report Dr Marks mentioned several small seams outcropping at the junction of Coal Creek and the Brisbane River. These he also considered economically unimportant. The Coal Creek syncline, the structural unit to which I refer these small seams, is structurally favourable but does not appear to contain payable coal, since these indications are the only ones noted from it. An analysis of this coal gives—

	Per cent
Moisture	2 05
Volatile H C	23 10
Fixed C	61 10
Ash	13 30

- (3) Dr Marks also noted thin coaly bands in the railway cuttings and the hills about Ottaba, but spoke of this area as being so disturbed as scarcely to be desirable for prospecting. My map shows that the Ottaba area lies on the Ottaba axis of sharp anticlinal fracturing and intrusion, so that even large deposits here would scarcely be payable.

Mr Morton† had examined two occurrences of coal in the Toogoolawah mountains.

- (4) The first of these, found in one of the heads of Black Jack's Creek behind Governor's Rock, was a 7-ft seam of good bright coal which was, however, standing vertically. Its analysis was—

	Per cent
Moisture	8·9
Volatile H C	23 4
Fixed C	60 6
Ash	7 1

He reported unfavourably on this, as the area was obviously one strongly affected by movement and intrusion, and very mountainous.

- (5) The second occurrence was at the head of Splitter's Creek, on the Stanley side of the divide. Here there were several small seams, also vertically disposed. My work shows that the Toogoolawah mountains may be regarded as a very

(f) —

unlikely area for the occurrence of payable coal. All the strata are affected by a disturbance which is probably the greatest of the Brisbane Valley, and which is accompanied by much the largest intrusions.

- (6) While on a coach journey from Esk to Nanango in 1901 Mr. Ball* noted several coaly outcrops on the road at the foothills to the Blackbutt Range as worth prospecting. I found here a number of seams of bright coal dipping gently to the east with a maximum thickness of about 20 in. But, half a mile to the east, the Stone House Disturbance affects the strata, and cuts out any possible extension of the coaly seams farther to the east, and I do not believe enough coal could be mined to justify the opening of even a small colliery. Nevertheless, this occurrence is the most promising I have seen.
- (B) The following occurrences are noted for the first time —
- (7) Two miles from Esk on the Esk-Murrumbidgee road in Por 56 par Esk, three small bands of carbonaceous material are seen. The structure is favourable, being a small syncline auxiliary to the Coal Creek syncline, but the coal is not there in sufficient quantities to warrant the establishment of a mine.
- (8) On Happy Creek, about half a mile below the Ironside Dam in Por 132 par Colinton, a 30-in seam of bright coal outcrops, accompanied by several smaller bands, interbedded with conglomerates and extraordinarily fossiliferous shales. The dip, however, was 50° N E. This coal outcropped in the strata uptilted by the Western Border Fault and the prolongation of the Ottaba axis of anticlinal fracturing. It was thought that the seams might be tapped in the gently dipping synclines to the east, but the seams were found not to be persistent along the line of strike.
- (9) Thin coaly bands, steeply tilted for the same reason as the Happy Creek seams, were seen on the road half a mile north-east of Happy Creek seams and in the gully to the east of the road.
- (10) On the road between Moore and Colinton a few thin coaly seams are seen. But this is in a region intensely disturbed by the strong Colinton axis of sharp anticlinal fracturing and intrusion, and is consequently of no promise.
- (11) Similar bands are seen on the road between Linville and Avoca Creek, but these are of no promise for the same reason as occurrence No 10.

(C) The following negative evidence is of value —

No indications of coal were seen in the ridges and gullies of the Glen Harding and Maronghi synclines, or in that part of the Wallaby syncline south of the Moore-Benarkin road, during traverses over these synclines. The Wallaby syncline north of the Moore-Benarkin road has not been prospected.

IX—SUMMARY AND CONCLUSION

In the Brisbane Valley between Esk and Louville a series of Triassic rocks is trough-faulted along the north westerly grain of the country into the Palaeozoic (including folded Permo-Carboniferous) formations. These Triassic rocks, the Esk Series, are freshwater basin deposits laid down by rapidly changing currents, with intensive contemporaneous volcanic activity. The Lower Esk Series is typified by very intense andesitic activity, with the formation of a great thickness of peculiar andesitic boulder beds, small sedimentary deposits being formed during periods of temporary cessation of volcanic activity. The strictly conformable Upper Esk Series, however, is typified by a thick development of rapidly varying sedimentary deposits, with interbedded flows and tuffs resultant from intermittent trachytic activity. Above the Upper Esk Series, the Bundamba sandstones, now all eroded away except from the southern part of the area west of Esk, were deposited without angular unconformity. In addition to the trough-faulting, the Esk Series has been strongly affected by sharp north-westerly directed anticlinal fracturing, accompanied by the intrusion of an important series of hypabyssal rocks, the Brisbane Valley Porphyrites closely related in mineralogical type to the flows and tuffs of the period of sedimentation. The time relations of the trough-faulting and anticlinal fracturing are unknown, but they both occurred before the extrusion of the Tertiary dykes.

It is concluded that the conditions of deposition and the type of folding of the Esk Series do not promise well for the occurrence of a large field of workable coal, but that the synclinal areas are worth more detailed mapping in the chance of the discovery of a deposit large enough to support a small colliery.

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Essential Oils from the Queensland Flora.

Part I.—*BACKEA VIRGATA*

By T G H JONES, D Sc, and M WHITE, M Sc

(Tabled before the Royal Society of Queensland, 28th April, 1930)

Backea virgata is a tall erect and closely branched shrub growing along watercourses in the Brisbane area, being particularly abundant and of vigorous growth on the banks of the Woogaroo Creek, Goodna. Its botany is described in the Queensland Flora (Bailey) ¹

On crushing the leaves a strong odour of cineol is readily detected. The yield of oil obtained on distillation was 1 per cent. Examination of its chemical constituents showed that the oil consisted very largely of d- α -pinene 50–60% cineol 30% together with aromadendrene, a sesquiterpene alcohol, and a trace of a lower alcoholic body diagnosed tentatively as pino-carveol.

In view of the large quantities of pinene and cineol present the oil has some economic value.

EXPERIMENTAL

353 lb of leaves and terminal branches collected along Woogaroo Creek, near Goodna, on the 21st August, 1929, and distilled on the 22nd, gave 1,560 ccs of oil, the greater part of the oil distilling over in a couple of hours.

The following constants were determined —

$d_{15.5}$	9021
n_{20}^D	1.4742
D	
$[\alpha]_D$	+18
Acid number	1
Ester value	nil
Acetyl value	17

No absorption in the usual reagents, except for cineol could be detected.

1,000 ccs of oil were fractionated under diminished pressure and the following fractions collected —

Fraction	Ccs	Temp Range °C	Pressure	$d_{15.5}$	n_D^{20}	$[\alpha]_D$
1	317	0 — 55°C	24 mm	8705	1.4679	+ 30.0
2	242	55 — 65°C	24 mm	8825	1.4670	+ 26.0
3	110	65 — 75°C	24 mm	9200	1.4602	+ 0.0
4	36	75 — 85°C	24 mm	9305	1.4691	— 3.0
5	53	85 — 105°C	24 mm	9500	1.4895	— 6.5
6	97	82 — 95°C	8 mm	9337	1.4958	+ 5.5
7	112	95 — 108°C	8 mm	9512	1.5005	+ 2.5
TOTAL	961	Resinous loss, 40 ccs				

Fractions 1 and 2 were repeatedly extracted with 50% resorcin solution to extract cineol

The residual oil after refractionation possessed the following constants —

d_{15}^4	·8641
n_{20}^D	1·4660
$[a]_D$	+43
b p	155–156°C

Identification with pinene was established by the usual oxidation to pinonic acid, the semicarbazone of which melted at 204°C No β pinene could be detected

Fraction 3 consisted of relatively pure cineol Independent determination of this constituent on the original oil gave a value approximating 30%

Fractions 4, 5, and 6 —The noticeable increase in density in fraction 5, with a diminution in fraction 6, pointed to a constituent of somewhat higher density in these fractions, with a higher boiling point than that of cineol but lower than that of the sesquiterpene fraction 6, and therefore probably a terpene alcohol They were accordingly refractionated as far as possible, and the small amount of resulting oil combined with phthalic anhydride by boiling with this reagent in benzene solution for several hours Decomposition of the acid phthalate gave an alcoholic body with the following constants —

d_{15}^4	974
n_{20}^D	1 4965
$[a]_D$	—23
b p	220°C

The constants appeared to agree only with those recorded for pino-carveol, a somewhat rare alcohol occurring in *Eucalyptus globulus*

Combustion Results—

Found C 79 1, H 10 8

$C_{10}H_{16}O_2$ (pino-carveol) requires C 78·9, H 10·5

Confirmation of the identity of the alcohol with pino-carveol was sought in attempts to prepare the phenyl urethane, but we were unable to obtain sufficient of this derivative for complete purification, although the melting point (79°C) approximated to that required for this derivative 82°C

This alcoholic body is only present in very small quantities in the oil, the total amount obtainable from the 1,000 ccs being only about 2 ccs It would therefore probably escape detection in small amounts of oil.

Fractions 6 and 7 were further refractionated and separated into a sesquiterpene and sesquiterpene alcohol fraction.

The sesquiterpene, purified by repeated distillation over sodium, possessed the following constants—

b.p.	92–95°C. (7–8 mms)
d_{15}^4	0.8181
n_{20}^D	1.4985
$[\alpha]_D$	+11

The usual colour reaction with bromine vapour suggested the presence of aromadendrene, the characteristic sesquiterpene of the Myrtaceae. The combustion results agreed with $C_{15}H_{24}$.

Sesquiterpene Alcohol —

The final fraction, purified as far as possible by repeated distillation, possessed the following constants —

b.p.	105–107°C (4–5 mms)
d_{15}^4	0.856
n_{20}^D	1.4992
$[\alpha]_D$	— 6

Combustion Results —

Found C 82.6%, H 11%

$C_{15}H_{24}O$ requires C 80.2%, H 10.9%

Evidently a sesquiterpene alcohol was the preponderating constituent of this fraction still in admixture with aromadendrene. Its small amount precluded further examination.

Our thanks are due to the Council for Scientific and Industrial Research for a grant which has defrayed the cost of collection of leaves, to Mr C. T. White for his usual botanical assistance, and to Miss D. Hill, M.Sc., who assisted in the collection of leaves.

REFERENCE.

- 1 Queensland Flora, F. M. Bailey, 585 (5)

The Physiographical Significance and Non-migration of Divides.

By E O MARKS, B E, M D

Two Maps

(Read before the Royal Society of Queensland, 26th May, 1930)

IN the theoretical consideration of stream development as described in physiographical literature generally, and particularly by that giant amongst physiographers, Professor W M Davis, the headward erosion of streams or migration of divides, with the changes resulting therefrom, have been given very great importance, and even a nomenclature implying origin by this theoretical process of development

Griffith Taylor and most other writers on Australian physiography have given a corresponding importance to the process in the interpretation of our own river systems. It is to be noted that they have usually given attention only to the river courses and none to the divides separating their basins

This paper is intended to draw attention to certain divides which seem to the writer to indicate that the fundamental theory cannot be entirely correct. An examination into the theory suggests, as do the divides themselves, that "migration" can only be of very minor importance except in very unusual circumstances in regions of great elevation, and that it is quite incapable of the results usually claimed for it

Professor Davis fully describes the theoretical migration of divides resulting from the encroachment by headward erosion of one stream at the expense of the drainage area of another less advantageously situated for erosion. This would take place more quickly in soft rocks than in hard, and lead to the development of valleys and streams in the softer rocks and so to a rearrangement of the drainage in accordance with geological structure

It is not desired here to recapitulate the details of the supposed stream development, with river captures and so on, and the nomenclature given, but it is necessary to emphasize the dependence of it all on the occurrence, as a very active denudational principle, of this encroachment by any stream possessing an erosional advantage over its competitor on the other side of a divide. Without this headward encroachment the whole scheme is void, and only in so far as this encroachment takes place can the scheme be valid

Structure and climate being equal on the two sides of a divide, if one side has a bigger fall, steeper slopes, and therefore more active streams than the other, denudation will be greater on that side, with a consequence that headward erosion will take place, the drainage area of the more active stream gaining at the expense of the less active one. There is, of course, no question that this must take place to some extent; view, such as one gets of the Toowoomba Range show it clearly, but the

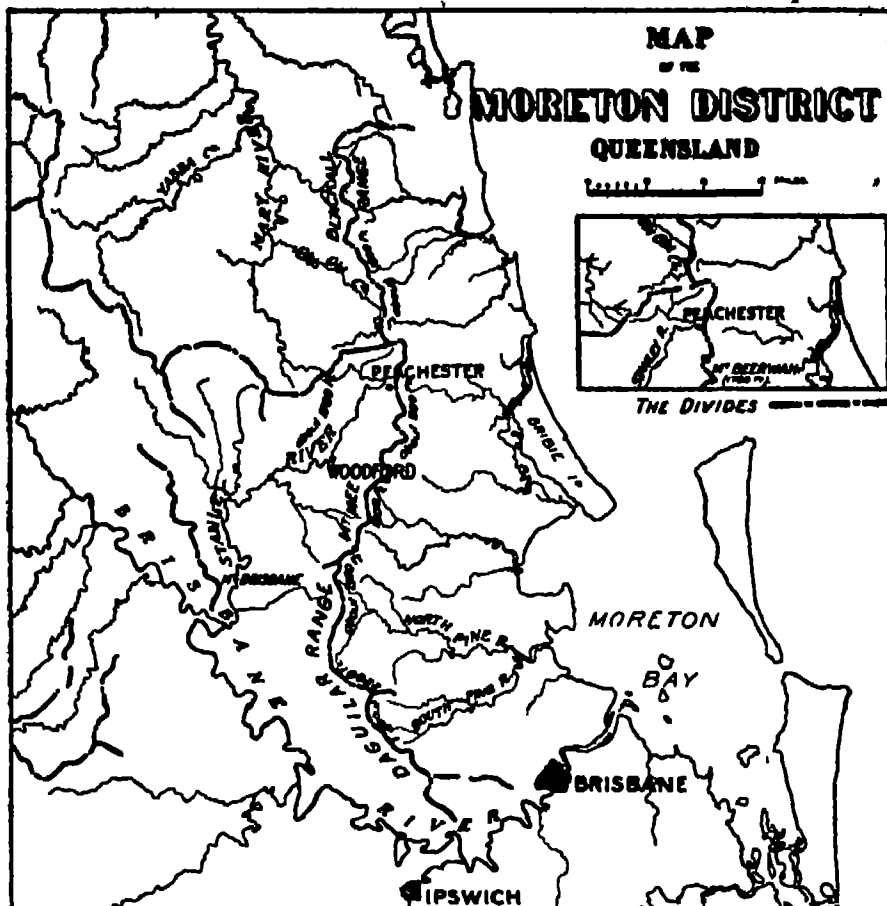
question raised here is as to whether the process does take place sufficiently to affect appreciably the general physiographical development

According to the theory the migration of a divide must necessarily be somewhat irregular, for it will depend on the relative slopes and stream gradients of the two sides, on the resistance of the rocks, on climate, vegetation, and probably other factors not so obvious. Since these conditions cannot be equal throughout, one portion of a divide must migrate more rapidly than another. If originally straight denudation must make it crooked. It could only remain straight if the original elevation, slopes, stream gradients, rock structure, climate, &c., were uniform throughout the whole length of the divide, which is practically an impossible occurrence. Apart from developing the linear outcrop of a resistant rock we may be quite certain that denudation could neither make a crooked divide straight nor develop a straight or evenly curved one. Only some geological structure could give rise to it, such as a faulting, folding, or warping of the earth's surface.

A straight divide must therefore be what Davis calls a "consequent" divide—i. e., a consequence of an original water parting. An irregular divide might also be "consequent," the result of some original irregular water parting, or it might result from subsequent denudation and be what has been termed "subsequent." It is to a consideration of some approximately straight divides and their bearing on the theory of migration that the writer would call attention.

To the north of Brisbane the D'Agular and Blackall Ranges form, with very minor local irregularities, one nearly straight divide, except at the southern end, where it bends from a north-south to a south-easterly direction. It separates the watersheds of the numerous short streams which run easterly courses directly into the sea, having courses up to 30 miles in length, from those of the streams which run westerly into the Upper Mary and Brisbane Rivers, the water in these having up to 180 miles to travel to reach the sea.

The geological structure is very varied, as is the elevation and character. At the southern end the rocks consist of the partly metamorphosed sediments we call the Brisbane Schists, and one or two small cappings of basalt. The elevation rises to over 2,000 feet. There is a gap near the head of the North Pine River where the elevation is down to 1,000 feet, but it rises again to the north, where the divide is on the tableland of Mount Mee at an elevation of 1,500 feet and composed of more basic schists and some basalt. After some 10 miles on the tableland the divide drops to about 500 feet for some 12 miles, separating here the wide valley of the Stanley (Jensen's Woodford peneplain) from the lower coastal country. The divide here is partly of deeply decomposed granite but mainly of soft sandstone, and from it rises the trachyte plug of Mount Beerwah to a height of 1,760 feet. North of Peachester, for another 12 miles or so the divide is on the eastern edge of the basalt capping which forms the Blackall Range tableland, about 1,500 feet high, the western fall being into Obi Obi Creek and thence to the Mary River.



The most interesting part of the divide for our present purpose is the 12 miles or more at an elevation of only 500 feet, composed of soft rocks, having a wide "peneplain" valley to the west of it and the low coastal plain to the east, while to the north and south the divide is on tablelands of harder rocks, with an elevation of about 1,500 feet. From the divide itself rises the trachyte plug to 1,700 feet, and the other Glass House Mountains rise in a similar way from the coastal plain, while to the west of the Stanley is a flat-topped mountain, more or less a continuation of the Blackall Range and 1,700 feet high. The Stanley itself near its junction with the Brisbane has cut a gorge through Mount Brisbane, the lower side of which is of much greater elevation than the low divide, and the higher side, Mount Brisbane, is over 2,000 feet above the sea.

It seems, therefore, perfectly certain that extensive denudation has taken place, while differential denudation would fully account for the low elevation and the character of this portion of the divide. How much has been removed it is impossible to say, but it cannot have been less than 1,000 feet to bring it up to the present level of the tablelands to the north, west, and south.

Now let us look at the map to observe the extent of encroachment by the very short streams running direct to the sea over soft sandstone country, these having obviously an enormous advantage as compared with the waters running into the Stanley with 180 miles to go, much of it over hard rocks. We look in vain, for the divide is deviated only in the most trivial manner, the deepest recess being less than 2 miles in from the eastmost prominence, and the mean position not being shifted westwards at all as compared with the higher divide to north and south. Moreover, any suggestion that the straight divide might be of the nature of a fault scarp is definitely precluded to the north by the geological structure (the basalt not being faulted down), and to the south by the occurrence of high ground to the east of the actual divide.

If we look at the map for signs of river capture as indicated by the directional changes in the streams, attention is at once caught by the uppermost portions of the Obi Obi and Stanley. Initially both these streams, the one on top of the Blackall tableland and the other below it, run parallel courses eastwards as if making straight for the sea, but when within a mile of the divide change their courses to the north-west and south-west. What the cause of this remarkable change in direction could have been we need not speculate upon, but this is certain, that if a sudden change of direction has any real value as an indication of river capture, then the Obi Obi and Upper Stanley with long courses and attacking from opposite directions have succeeded in capturing the headwaters of two adjacent short streams whose present lower courses are at a much lower elevation than either of the attacking streams. Which is absurd.

A consideration thus of the D'Aguiar-Blackall divide shows that stream development has not taken place as it should have done, and indeed must necessarily have done according to the widely accepted theory.

Since straight or regularly curved divides must be original divides and not "subsequent" we may inspect the map for other straight divides and see what indication for or against migration these may give.

Taking first the Main Divide—Dividing Range is a misnomer—which separates the Pacific drainage from the western flowing rivers, we observe a regular nearly straight length of almost 300 miles separating the Burdekin waters from the Thomson, Barcoo, and Flinders. This divide traverses the tableland on which are the inland basins of Lakes Buchanan and Galilee, and these introduce a choice in their vicinity as to where the Main Divide is situated. Dr. Danae regarded them as evidence that the divide is recent. There is certainly no suggestion of irregular migration in this 300 miles which runs from the chief water-parting centre of the North, whence the drainage runs by the Einarleigh, Gilbert, and Flinders into the Gulf of Carpentaria, by the Thomson into the inland system and by the Burdekin to the Pacific, to the similar parting centre near Tambo whence water drains into the Barcoo of the

inland system, the Warrego of the Darling-Murray system, the Nogoa of the Fitzroy and the Belyando of the Burdekin system, the two latter both entering the Pacific

For about 150 miles from near Tambo the divide is irregular, but the portion running nearly east and west for 150 miles from near Mitchell to near Chinchilla is again regular and separates the Condamine waters of the Darling-Murray system from the Dawson of the Fitzroy system and the Auburn of the Burnett. It is to be noted that the latter has not eroded back the divide in comparison with the Dawson, which has a much longer course

Near Chinchilla the direction of the divide changes and runs nearly straight for 100 miles in a south-easterly direction, parting the Condamine waters on the one side from those of the Boyne (Burnett) and Upper Brisbane. Though these two have very different courses, and have both been competing against the Condamine waters on the other side of the divide, there is no deviation to indicate that one has gained more than the other, as it surely must have done according to the theory. The divide remains straight, apparently in its original position

In the region of Toowoomba the map is very suggestive of some minor nibbling back of the divide by the heads of Lockyer Creek, of the Brisbane River basin. Just here there is no range as one approaches the divide from the west or Darling Downs side, and the Lockyer is draining the scarp of a tableland some 1,500 feet above it. Even with this great advantage the headward nibbling does not seem to be a matter of more than 3 or 4 miles, and the wide Lockyer valley a few miles from the escarpment has the characters of an old stream

South from Toowoomba the Main Divide is a range of mountains as approached from the west, nearly as steep though not so high as on the eastern side. The divide varies in elevation from about 2,000 feet in the gaps to 4,000 on the peaks, but shows no appreciable deviation to indicate headward encroachment by the varied streams draining its lower eastern side, although the gorge cut by Reynolds Creek through the trachyte mountain of Mount Edwards shows that denudation of at least 2,000 feet has occurred

Apart from the Main Divide there is one remarkably straight line of water parting which immediately catches the attention on looking at the map of Queensland. This runs for 250 miles from near the coast at Mackay southwards to near Camboon, where it turns a little west of south and continues straight for another 100 miles to join the Main Divide. This long regular water parting separates the basin of the Mackenzie-Dawson system from the streams on the east of it—namely, the very short coastal streams in the Mackay-St. Lawrence region, the lower part of its own combined stream the Fitzroy, the subsidiary basin of the Don, and the Burnett waters. This long line is only crossed by two streams, the Don crossing it from east to west to join the Dawson, and the main combined stream crossing it from west to east on its way to the sea

This long straight divide, like the parallel courses of the Dawson and Mackenzie, must have some, probably the same, tectonic origin. It varies greatly in character and geological structure, and in the length of the streams attacking it, but denudation has not caused any serious deviation. One could hardly suppose that the Lower Fitzroy alone of all the streams attacking it from the eastern side has succeeded in breaching it and also in capturing the main stream, while the Don a tributary of that main stream attacked and breached it from the west, capturing some of the eastern waters, the while the rest of the divide has not been deviated to any appreciable extent, even by the very short coastal streams at the northern end.

The late Dr. Danes suggested that the compound systems of the Burdekin and Fitzroy had formerly been inland basins which had found egress to the sea by the present combined lower streams. Such an explanation would fit well with the apparent non-migration of the divide if the egress was found by overflow through a low or lowered part of the divide rather than by the usual idea of river-capture by headward encroachment, and similarly for the Don in the opposite direction.

A consideration thus of these Queensland divides, some at least of which have been subjected to extensive denudation, does not seem to show that headward encroachment, with resulting deviation, has taken place to any significant extent, as it certainly should have done if the physiographical theory is correct. Though formerly accepting it, the writer has thus felt compelled to examine the theory for some flaw in what had previously appeared sound reasoning. Whether the explanation now offered is the true one is very questionable, for like the original theory it is purely theoretical. What we must face is the cold fact that migration has not taken place to any appreciable extent in just those very circumstances where it would necessarily have done so had the present widely accepted theory been substantially correct.

In his essay on the Geographical Cycle, W. M. Davis has a paragraph on the development of graded valley sides, a grading which can only take place after the stream itself has become graded. He says, "Maturity is passed and old age entered upon when the hill-tops and hill-sides as well as the valley floors are graded." The grade of both stream and valley will become flatter as denudation lowers the general level and so alters the conditions. The grade of a valley side must depend on the climatic conditions, the nature of the rock, and the elevation of the valley side. Once graded, a flattening of the grade can only take place by a reduction of the elevation. If the elevation persists then the grade must also persist suitable to that elevation, so that the grade will not become flatter, for instance, on the sides of a tableland until the level of the tableland is lowered.

We must fully realise that, except for the trivial effect of river meanders, denudation is entirely vertical. A waterfall is only cutting down the bed of the stream, it is not cutting it back in any way, or altering the drainage area, it is merely lowering an already existing valley.

Davis's diagrams give the impression of a young stream cutting back and gaining more ground as it entrenches itself, whereas the position and drainage area must have been determined for it *ab initio*. The water collected in the original depressions would carve down and develop the valley. Since it is the water that is doing the carving, the valley must be formed where the water happens to run, and the entrenchment of the valley can only follow up the already existing stream, for elsewhere there is no water. It cannot pick out soft structures since the lowering of the surface, no matter how soft, cannot get below the streams into which it drains. As a stream only cuts down its bed, after the manner of a saw in its groove, it has got to cut whatever rocks it meets with in its groove.

The cutting is done by rain-water particularly when collected into streams and (it must be repeated) is entirely vertical. The original water parting, where there is no stream, must therefore be quite unaffected except for the actual rain falling directly on it, until the valley is opened out and the stream and valley sides graded right back to the divide. Before that no migration from denudation is possible, as the water on each side of the parting would merely flow each way removing its own debris.

The actual head of a stream is only the end of its valley, the terminal valley side, and it must be graded by the same controls as determine the rest of the valley sides. If, for simplicity, we suppose a stream heading in a plateau scarp, the terminal side having a grade of 1 in 10, each 100 feet vertically removed from the valley side would only shift the divide 1,000 feet, and a removal of 500 feet would be necessary for a migration of one mile. One in ten is not a steep valley side, and the steeper the grade the less the shift. With a grade of 1 in 5, 1,000 feet would have to be removed for a migration of one mile. Thus, while on a steeper grade denudation is doubtless more rapid, a much greater vertical depth of material has to be removed to achieve the same result, neutralising the advantage to some extent. When further we remember that the steeper the grade the more perfect the drainage, and therefore the less chemical disintegration of the rock, the advantage of a steep slope over a less steep one may be much less than would appear at first sight.

Now it is only when the streams and valley sides are graded that there can possibly be any headward encroachment whatsoever, for it is only then that the denuding of the valley sides can start to cut back the divide. This is the stage, according to Davis, when maturity has been reached and old age is beginning. In the theory as propounded by him, the rearrangement of drainage and formation of "subsequent" streams ~~take place~~ in the earlier stages, but it follows from the above considerations that the encroaching stream must have at least attained maturity. It follows also that the lateral shift resulting from denudation of the valley sides—the migration of the divide—can only be very slight except in regions of great elevation, and then only if the stream were cutting back into the edge of a plateau. Even so, an enormous vertical

depth of material would have to be removed from the valley sides to achieve any migration of physiographical significance. Where moderately steep slopes occur on both sides of the divide, the shifting of the divide must be quite negligible, for both sides are acting, until such time as the divide is lowered to become a plateau scarp, or in other words until the basin of the weaker stream has become a fully developed peneplain.

That these exceptional circumstances may sometimes occur there is no doubt, but they must be very rare. It must be rare indeed for the migration to be sufficient to tap a stream of any considerable magnitude. One might as easily imagine a divide being lowered sufficiently for an exceptionally high flood to go over it and thus start a new direction of flow, but this would be river dumping rather than capture. The conditions to make it possible would also be very rare.

The physiographical conception of a reversal of drainage in the lower part of a stream resulting from its capture higher up is extremely improbable, since the part immediately below the capture would become a new divide, and the recession of it would be that of a valley side, not of a stream, unless the floods in the lower part were sufficiently high to flow back over the new-formed divide. When this improbability is added to the improbability of river-capture at all, the theoretical development of a reversed or "obsequent" stream is just about impossible.

Those of us who have seen Mount Edwards gorge where a comparatively small stream has cut down through the trachyte mountain which a small deviation would have avoided, and the similar behaviour of the Stanley at Mount Brisbane where also a small deviation would have avoided the obstruction, cannot fail to be impressed with the manner in which these streams have had to stay "put," and have not selected the softer rocks in the vicinity. Now it would seem that we must also regard the divides as more or less fixed, except in somewhat unusual circumstances, while even in those circumstances the migration must seldom be of importance. If this conclusion is correct and we accept the general fixity of divides, then all that part of physiographical theory which depends on their migration must be discarded.

In concluding, the writer desires to state that since the paper is concerned rather with general physiographical theory than with local problems, and has considered the local features from an entirely different viewpoint from previous writers, little reference to or criticism of previous work has been made. There are points of agreement and disagreement, but these have purposely not been mentioned, so as not to cloud the main issue, which is threefold —

- 1 That in studying physiographical developments the divides must be considered equally with the stream courses.
- 2 That in the D'Aguiar-Blackall divide nature has performed for us an almost ideal experiment, with proper controls, on the ability of denudation to cause a migration of

the divide. In the experiment this action has been negligible. It is only one clear experiment, but a consideration of other divides confirms the finding that headward encroachment by streams is a much less important principle than the accepted theory would indicate.

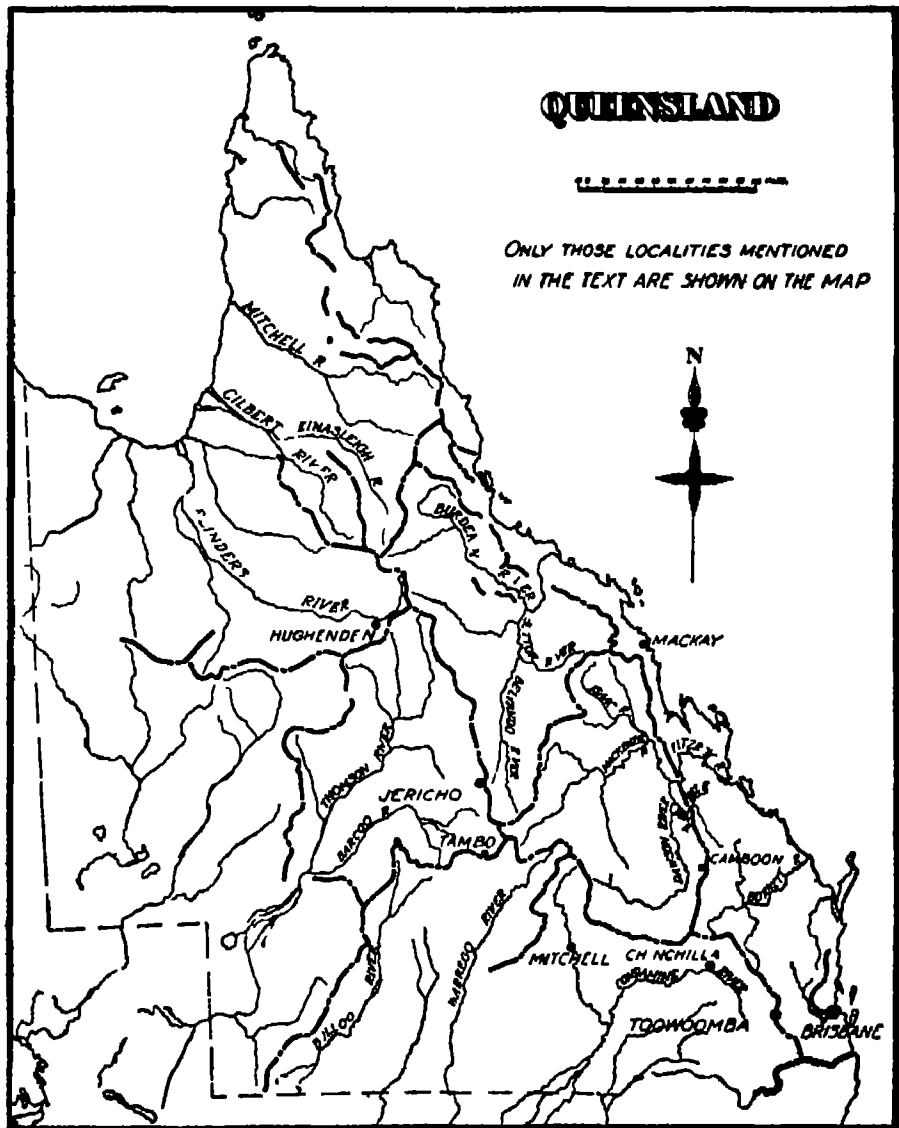
3 That the general theory must in consequence be seriously modified in so far as it depends on the migration of divides.

The writer further desires to express his thanks to Dr W H Bryan for suggestions and modifications in the composition of the paper.

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The references to Professor W M Davis's works are from "Geographical Essays" by William Morris Davis, edited by Douglas Wilton Johnston and published by Ginn and Company.



Chaetognatha from the Society Islands

By B B GRAY, FLS

(Twelve Text-figures)

(Communicated by Mr F A Perkins, B Sc Agr, to the Royal Society of Queensland, 26th May, 1930)

THE Chaetognatha discussed in this paper were all taken in a surface net in Papetoni Bay, Moorea Island

The collection was made in sixteen hauls, irregularly spaced over the period of twelve months, all made with the same net and steaming over about the same course

Ten species are represented, including one apparently new to science, which are embraced by two genera, *Sagitta* and *Pterosagitta*

COINCIDENT OCCURRENCE OF SPECIES OF CHAETOGNATHA IN PAPERONI BAY

—	Oct 22, 2	Nov 7, 10, 13	May 21	Aug 10, 13	Sept 28, 29	Oct 1930 1, 9, 11, 12, 13, 23
<i>S. bipunctata</i>				+		
<i>S. inflata</i>	+	+		+	+	
<i>S. frederici</i>	+	+		+		+
<i>S. minima</i>	+					+
<i>S. neglecta</i>		+				+
<i>S. planctonika</i>				+		
<i>S. regularis</i>			+			
<i>S. tenuis</i>				+		
<i>S. oceanica</i> , n. s.				+	+	+
<i>Pt. draco</i>			+			+

Of the above species *S. inflata* Grassi alone varied from the type description. Normally the lateral fins are separated from one another by from 9% to 15% of the total body length. All the Moorea specimens were examined while alive, and it was found that the anterior and posterior fins were nearly always confluent, also the anterior fin occasionally had a clear outer zone as well as a clear inner zone and anterior portion, while in one case the anterior fin was entirely rayless. The individuals were all very small for this species, but as all the other characters agree with the published descriptions the establishing of a new species did not seem justified, and it is likely that this newly noticed character of the fins has not been observed before owing to damage to the very frail structures.

Sagittia oceanica sp. nov.

A transparent, robust form, which keeps its shape well

Length—4.4–8.3 mm

Breadth—5%–7% total length

Tail—29%–38% total length

Anterior teeth—5–8

Posterior teeth—15–20

Jaws—6–7 The tips of some are slightly hooked

Anterior fin—14%–22% total length It is rayed obliquely throughout and reaches the ventral ganglion

Posterior fin—25%–29% total length, rayed obliquely throughout, almost reaches the seminal vesicle, less than 50% in front of the tail septum The fins are separated from one another by from 3%–8% of the total length of the animal

The ovary reaches the region of the ventral ganglion when mature and contains a single row of large and small ova

The seminal receptacle is small and round

The seminal vesicle is small but conspicuous, almost reached by the posterior fin, and widely separated from the tail fin

Intestinal diverticulae are present

Two rows of sensory papillae bearing setae are present, extending from the neck region to the tail In young specimens the tips of the setae comprising each tuft are joined together and the whole spirally twisted to the shape of a candle flame (Fig 2) In later life the tip of the composite tuft gets broken and the released setae straightened themselves out

S. oceanica is immediately distinguishable from all other species with sensory papillae and setae by the absence of the collarette

The new species was taken in five hauls in Papetoai Bay, Moorea

FERTILISATION OF THE CHÆTOGNATHA

In a paper on the spermatogenesis of Chætoagnatha, Lee (1888) described fertilisation in which the spermatozoides penetrated the septum between the body and tail cavities and so reached the ovaries direct, and Stevens (1903) observed a close fertilisation of *S. bipunctata* In Fig 5, which is a *Camera lucida* drawing of the region about the tail septum of *S. oceanica*, two bundles of spermatozoides can be seen in the inner portion of the seminal receptacle which seems to support their observations Unfortunately these were not seen until after the animal was dead, and so it was not possible to make further observations of the route taken, but the presence of the bundles of spermatozoides in the seminal receptacle of *S. oceanica*, at any rate, may be due to some accidental fracture of the septum, such as might easily be caused by the presence

Fig 1

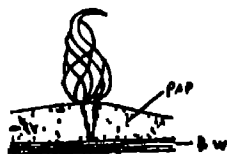
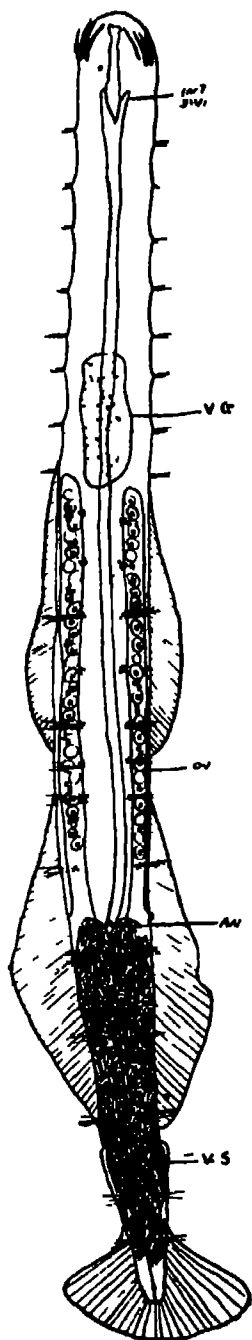


Fig 2



Fig 3



Fig 5

Fig 6

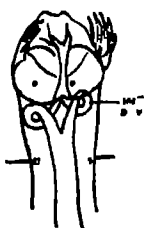
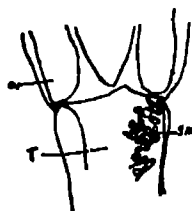


Fig 9



of some vigorous parasite, such as a nematode or trematode, as the presence of seminal vesicles in all species, and of large and conspicuous ones in many, would seem to point to a more ordinary functioning of the male parts in the majority of cases

The suggestion of a normal ejection of the male product is borne out by observations made on living specimens of *S. enflata* taken during the month of October. During this month the male products were ripe. The rounded sperm morulae gradually became elongated (Fig 8) and formed spindle-shaped bundles, some of which were ejected whole through the seminal vesicle with the spermatozoides of which they were composed vibrating rapidly, while others broke up in the tail itself (Fig 7). The bundles that were ejected into the water broke up during, or immediately after, ejection and the individual spermatozoides wriggled rapidly about.

The ova were apparently ripe at the same period, but no movement was observed in the ovary.

PARASITES

During October several individuals of four species collected were found to be parasitised by trematodes, nematodes, or cysticerci —

	Parasite	Region Infected
<i>S. enflata</i> 1	Trematode	Tail coelome
<i>S. enflata</i> 2	Trematode	Ovary
<i>S. fridrici</i> 1	<i>Camallanus trispinosus</i>	Intestine
<i>S. fridrici</i> 2	Cysticercus	Body coelome
<i>S. oceanica</i>	Trematode	Body muscles
<i>Sagitta</i> sp	Trematode	Tail coelome

The *Distoma* found in *S. enflata* is apparently identical with that figured by Scott (1896).

The trematodes seem to be able to force their way out through the body wall of the *Sagittæ* without much difficulty, and to move about in the muscles as they like. The nematodes are also extremely vigorous, and the presence of either one or the other in the tail coelome probably renders the male products useless, as the sperm morulae are broken up by the constant movements of the parasite. As suggested above, the former presence of a parasite that forced its way from the body cavity to the tail cavity might account for the presence of the sperm bundles in the region of the ovary as shown in Fig 5, especially as the sperm morulae are generally in active motion, passing in a continuous stream up the outer wall of the tail coelome, and down again along the septum separating the two portions of the tail cavity. Fig 5 is of an individual captured during October when several specimens were found to contain parasites.

A MEAL TAKEN BY *S. ENFLATA*

At 4 o'clock a small individual of *S. enflata* was seen to attack an *S. fridrici* of about half its size. The victim was seized by the head,

Fig 7

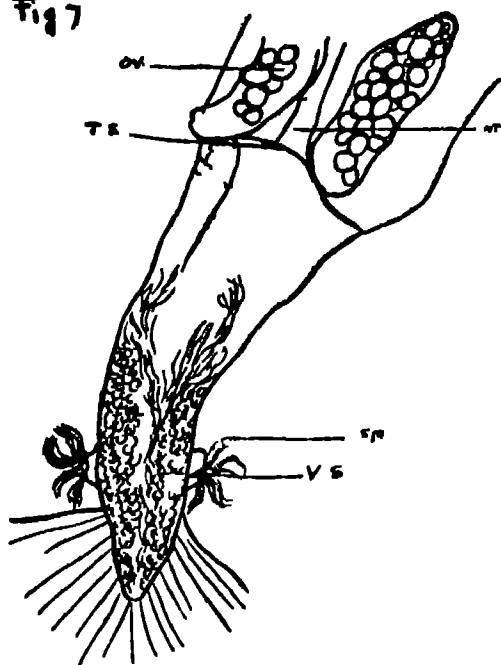


Fig 9

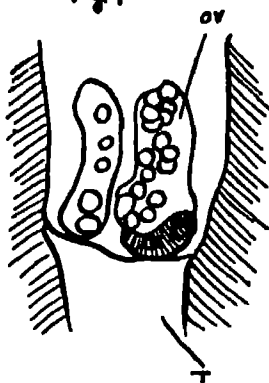


Fig 10

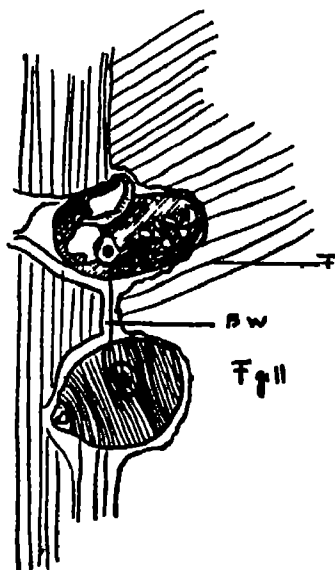
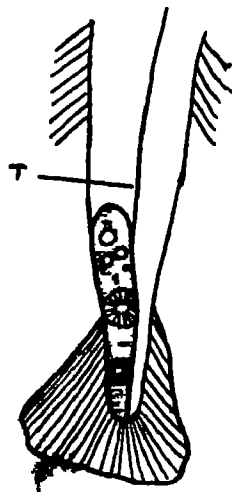


Fig 11

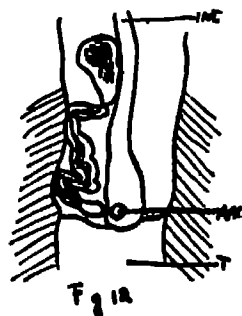


Fig 12

quivered slightly, but made no attempt to escape. It was swallowed straight down the intestine, and at 4.8 the head had reached the region of the anus. A rotary motion now commenced in the intestine of the eater, and at the same time the body of the eaten was moved up and down in the intestine, and this crushing motion gradually broke up the muscles until by 4.20 only the jaws, skin, and gut were intact, and the rest of the body was quite fluid. All nourishment had apparently been extracted by 4.40, when the remains were ejected through the anus, as a small shapeless mass, with only the jaws to show what it had once been.

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EXPLANATION OF FIGURES.

(All from *Camera lucida* drawings.)

- Fig. 1—*Sagitta oceanica* sp. nov.
 Fig. 2—*S. oceanica*. Sensory papilla and setæ bundle from immature specimen
 Fig. 3—*S. oceanica*. Posterior teeth
 Fig. 4—*S. oceanica*. Anterior teeth
 Fig. 5—*S. oceanica*. Region of tail septum, ventral view
 Fig. 6—*S. oceanica*. Head and neck, showing intestinal diverticulum
 Fig. 7—*S. enflata*. Showing ejection of spermatozooids
 Fig. 8—*S. enflata*. Showing changing sperm morulae
 Fig. 9—*S. enflata*. Trematode in ovary
 Fig. 10—*S. fridrici*. Trematode in tail coelome
 Fig. 11—*S. oceanica*. Trematode escaping through body wall, drawn by reflected and transmitted light
 Fig. 12—*S. fridrici*. Cysticercus in body coelome

AN, anus; BW, body wall; F, fin; INT, intestine; INT DIV, intestinal diverticulum; OV, ovary; PAP, papilla; RS, seminal receptacle; SM, sperm morula; SP, spermatozooids; T, tail; TS, tail septum; VG, ventral ganglion; VR, vestibular ridge; VS, seminal vesicle

Essential Oils from the Queensland Flora.

Part II.—*AGONIS ABNORMIS*

By T. G. H. JONES, D. Sc., and M. WHITE, M. Sc.

(Tabled before the Royal Society of Queensland, 26th May, 1930)

The genus *Agonis* belongs to the large family Myrtaceæ and consists of about sixteen species, ten of which occur in Western Australia and six in Queensland, one of the Queensland species, namely *Agonis abnormis*, stretching into northern New South Wales.

Agonis abnormis is a tall shrub or small tree common along river banks in South-eastern Queensland from Stanthorpe to the Wide Bay district, in the latter district being fairly common along Tinana Creek. It has a trunk with the rough bark persistent at the base but shed in ribbons or flake like pieces about halfway up, leaving the upper bark quite smooth. The leaves are narrowly lanceolate in shape, averaging about 1 to 12 inches in length, the flowers are white, the stamens 20 or more in number, the capsules small and opening in 3 valves. The species was originally described as *Leptospermum abnorme* by Mueller, but was later transferred to the genus *Agonis* by White and Francis.¹

Our supplies of leaves for the present investigation were obtained from the banks of the Blunda Creek, 400 lb. of leaves and terminal branches collected on 8th August, 1929, and distilled on 9th August, yielded 1,180 ccs. of oil or 6%, while from 900 lb. of leaves collected on 9th December, 1929, 2,810 ccs. of oil were obtained.

Little essential difference was observed in the two samples of oil thus obtained.

Examination of the oil as far as it has proceeded shows that it consists of dextro α -pinene (30–40%), sesquiterpenes 60%, and the residue 5–10% sesquiterpene alcohol.

The sesquiterpene fraction possesses physical constants and gives colour reactions similar to those given by aromadendrene, the characteristic sesquiterpene of the Myrtaceæ. Although several investigators have examined this sesquiterpene—in particular that obtained from *Eucalyptus nova anglica*²—very little can be definitely stated regarding it. Semmler³ considered that it consisted essentially of a mixture of two distinct sesquiterpenes, but Briggs and Short express as the results of their investigation the opinion that essentially only one such body is present.

The essential oil from *Agonis abnormis* is remarkable in containing a relatively large amount of this sesquiterpene, probably more so than any other oil yet examined, and in view of the ready availability of this oil it has appeared to us of interest to examine the sesquiterpene fraction in detail. The main difficulty in connection with the chemistry of aromadendrene seems to be that it cannot be definitely asserted that what is

usually described as aromadendrene in various essential oils is always the same substance or mixture of substances, the similarity of physical constants and colour reactions being not sufficiently diagnostic for the purpose

Although our examination of the sesquiterpene fraction of *Agonis abnormis* has not proceeded sufficiently far to enable us to give precise information regarding its chemistry—the details of which are reserved for a future communication—it is possible to state that at least two sesquiterpenes and possibly three are present, their separation involving prolonged and tedious fractionations

EXPERIMENTAL

The essential oil, pale yellow in colour and of pleasant odour, possessed the following constants —

d_{15}^4	9040
n_D^{20}	1.4905
$[\alpha]_D$	+ 9
Ester number	7.4
Acetyl value	16
Acid number	17

A combustion of the oil showed that it contained very little oxygen and consisted essentially of hydrocarbons only a trace was dissolved in 8% sodium hydroxide solution

2,400 ccs of the oil were distilled under diminished pressure and the following fractions collected —

Fraction	Distillation Temp	Volume	d_{15}^4	n_D^{20}	$[\alpha]_D$
1	0–75°C (29 mm)	525 ccs	8647	1.4836	+ 43
2	80–95°C (5 mm)	1,350 ccs	9091	1.4962	+ 2.5
3	95–105°C (5 mm)	268 ccs	9255	1.4998	— 1
4	105–110°C (5 mm)	165 ccs	9695	1.5002	— 10
TOTAL		2,308 ccs			

Residue and loss 92 ccs

Fraction 1 consisted almost exclusively of α -pinene. On further fractionation and distillation over sodium this substance was isolated in a high degree of purity with the following constants —

d_{15}^4	863
n_D^{20}	1.4854
$[\alpha]_D$	+ 47.6
b.p.	155°C

Its identity was established by the usual oxidation to pinonic acid and the preparation of the semicarbazone M.P. 207°C. No β -pinene could be detected.

Fractions 2 and 3 were further fractionated and 1,800 ccs of sesquiterpene obtained. The constants determined were as follows:—

$d_{15.5}$..	. 9121
$[\alpha]_D$.	+ 2
n_D^{20}	.	1.4990
b p	.	78–86°C at 5 mms.

These are in fair agreement with those usually quoted for aromadendrene, and the usual colour reaction with bromine vapour was also shown. As indicated in the first part of the paper, the sesquiterpene fraction is essentially a mixture of isomers, and, in view of the prolonged series of operations necessary to separate the constituents in a state of approximate purity, further details regarding the chemistry must be deferred for a subsequent publication.

Fraction 4 was found on further fractionation to consist of sesquiterpene alcohols in admixture with sesquiterpenes and probably also a mixture of closely similar isomers difficult to separate.

We have also commenced investigations of the other *Agonis* species of Southern Queensland.

Our thanks are due to Mr C T White for his usual botanical assistance, and to the Commonwealth Science and Industry Research Fund, which has defrayed the initial cost of the oil.

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- 1 Botany Bulletin 22, Department of Agriculture and Stock, Brisbane, p. 20
 - 2 Smith and Baker. A research on the Eucalypts. Briggs and Short, Journal Chemical Society, 1928, p. 2524
 - 3 Ätherischen Öle, 1905, 11, 530
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The Genus *Oxyscelio* Kieffer, its Synonymy and Species, with a description of one new Genus (Hymenoptera: Proctotrypoidea).

By ALAN P. DODD

(Tabled before the Royal Society of Queensland, 30th June, 1930)

In the Australian Scelionid fauna there is a homogeneous group of many species, whose generic position has given me considerable cause for thought, several of the species have been described in *Scelomorpha* Ashmead, two in *Dicroteleia*, and various others in my collection remain unnamed

Scelomorpha was based on a male of *S. longicornis* Ashmead from Brazil, a second species, *S. bisulca* Ashmead, from the United States, was doubtfully included (Bull U S National Museum, vol 45, 1893, p 239) In 1909 and 1910 Kieffer added six new species from Brazil and Peru Previously that author had described *S. flavipes* from Australia as a doubtful member of the genus, but later (1916) transferred it to his genus *Psilanteris* Being in doubt as to the Australian species being congeneric with *S. longicornis*, I submitted examples of *S. rugulosa* Dodd to Mr A B Gahan of the U S National Museum, who kindly compared them with the type of *longicornis* and supplied me with the following notes — "In my judgment *S. rugulosa* and *S. longicornis* are not congeneric In *longicornis* the pronotum is quite different, being partly dorsal and carinately margined in front, the marginal vein is thickened to form a small rounded stigma, the first segment of the abdomen lacks entirely the deep fovea at base and is without an enclosed area, and the entire body, including the eyes, is covered with conspicuous long hairs " A sketch by Mr Gahan of the thorax and wing venation represents an insect which is clearly not congeneric with the Australian species

Subsequently the late Professor C F Baker, of the Philippine College of Agriculture, loaned me the cotypes of several Philippine Scelionids, including *Camptoteleia carinata* Kieffer and *Xenoteleia flavipennis* Kieffer, genotypes respectively Examination of the former insect at once proved its generic identity with the Australian species of *Scelomorpha* and *Dicroteleia*, while *X. flavipennis* possessed no characters which, in my opinion, excluded it from *Camptoteleia*

Having established the fact that *Camptoteleia* Kieffer and the Australian species of *Scelomorpha* and *Dicroteleia* were identical generically, that many species of the genus occurred in the Philippines

and in Australia, and that a congeneric species, *Sceliorompha ceylonensis* Dodd, had been described from Ceylon, I made a careful comparison of the descriptions of other Oriental genera and species erected by Kieffer. This investigation has resulted in my offering the following synonymy of several genera, or of certain authors' interpretation of genera, in which *Dicroteleia* Kieffer, *Camptoteleia* Kieffer, and *Xenoteleia* Kieffer are regarded as being identical with *Oxyscelio* Kieffer —

OXYSCELIO KIEFFER

Zeitschr Hym Dipt, vol 7, 1907, p 310, genotype *O foveatus* Kieffer from Java

Dicroteleia Kieffer, Notes Leyden Museum, vol 30, 1908, p 92, genotype *D rugosa* Kieffer from Java. Dodd, *Proc Royal Soc Qld*, vol 26, 1914, p 105

Camptoteleia Kieffer, *Insecta*, vol 3, 1913, p 387, genotype *C carinata* Kieffer from the Philippines

Xenoteleia Kieffer, *Insecta*, vol 3, 1913, p 390, genotype *X flavipennis* from the Philippines

Sceliorompha (not Ashmead) Kieffer, *Beilm Ent Zeit*, vol 51, 1907, p 296, Dodd, *Trans Royal Soc South Aust*, vol 37, 1913, p 139, *Archiv fur Naturg Berlin*, vol 79, 1913, p 165, *Proc Royal Soc Qld*, vol 26, 1914, p 103, *Trans Ent Soc London*, 1919, p 349, *Proc Royal Soc Qld*, vol 38, 1927 p 128

Hoploteleia (not Ashmead) Dodd (part), *Trans Royal Soc South Aust*, vol 37, 1913, p 176

Psilanteris Kieffer (part), *Bioteria*, vol 14, 1916, p 177

Scelio (not Latreille) Girault, private publication, Brisbane, 1926

DISCUSSION OF THE GENERIC CHARACTERS

Examination of many Australian species has thrown considerable light on the variability of certain characters that might be regarded of value for generic distinctions, and has made possible an understanding of the limits of the genus. As previously stated, the identity of *Camptoteleia*, *Xenoteleia*, and the Australian species described in *Sceliorompha* and *Dicroteleia* has been established from a study of type or cotype material. On the other hand, the genotypes of *Oxyscelio* and *Dicroteleia* have not been seen by me, and, as the proposed sinking of the several genera may be open to question, an attempt is made to justify the suggested changes.

A comparison of Kieffer's descriptions of *Oxyscelio foveatus*, *Dicroteleia rugosa*, and *Camptoteleia carinata*, genotypes respectively, reveal many striking resemblances but few differences that would warrant separation. In each case either in the generic diagnosis or in

the description of the species, Kieffer stresses the fact that the submarginal vein is far removed from the costa, the marginal vein is punctate or square, and the postmarginal vein is absent. This combination of venational characters, particularly that of the remoteness of the submarginal vein from the costa, is, in my opinion, an outstanding feature of the segregate. The stigmal vein may branch off a little before the submarginal vein joins the costa, as in *Camptoteleia bifurcata* K. and *Dicroteleia rugosa* K., or from the punctiform or square marginal vein.

It will be observed that in the above three genotypes Kieffer mentions the presence of a median carina on the mesoscutum, a character on which he places considerable generic value. Among an extensive collection of Australian Scelionidae I have met this character in two genera, viz., *Hoploteleia* Ash. and the segregate under discussion, but it may or may not be present in species closely related and clearly congeneric. For example, *Scelionomorpha rugulosa* Dodd can be distinguished with difficulty from a species which appears to be *S. flavipes* Kieffer except that the median carina occurs in the former but not in the latter. Again, Kieffer himself states that the carina is not present in *Camptoteleia spinosiceps* in contradistinction to the various other species that he described in that genus. So much importance did that worker place on the character that he transferred the species originally designated *Hoploteleia carinata* Kieffer (1913) to *Camptoteleia* as '*C. perplexa* Kieffer (1926), the specific name being preoccupied by *C. carinata* Kieffer (1913), I have examined a cotype of this species which possesses a long postmarginal vein and is truly a species of *Hoploteleia*, its correct name being *H. serena* Dodd (1919), the name *carinata* being preoccupied by *Hoploteleia carinata* Cameron — *Apegusoneura carinata* Cam (1912). Here it may be remarked that the Australian *Hoploteleia elevata* Dodd bears the median carina on the mesoscutum.

Another character of the segregate is to be found in the metanotum which bears a prominent plate, usually transverse but subject to some modification. Of *Oryscelio foveatus*, Kieffer states, "metanotum longitudinally striate, nearly square, narrower and one-third shorter than the scutellum, covering but not projecting beyond the median segment." This is not the usual form of the metanotum in the Australian species but occurs in *Dicroteleia solitaria* Dodd. Kieffer describes this sclerite in *Camptoteleia carinata* as "with two small pointed teeth nearly contiguous at the base", my notes on a cotype of *carinata* read "metanotal plate hollowed out, the posterior margin depressed, the lateral margins prominent, the posterior-lateral angles raised and prominent." The excavated type of the plate with the raised lateral margins and prominent, although usually rounded, posterior-lateral angles is dominant in the Australian forms. In his 1926 description of *Dicroteleia rugosa*, Kieffer does not mention the metanotum, but in the generic diagnosis states "metanotum unarmed, forming a narrow cross-stripe." Of *Xenoteleia flavipennis*, Kieffer merely mentions that the

metanotum is transversely foveate, whereas my notes made from a cotype state that the metanotal plate is transverse, its posterior-lateral angles rounded.

The propodeal characters are rather different than in most *Scelionid* genera. The propodeum is short medially, long laterally, and there are long true lateral carinae some distance from the median line. The posterior margin is broadly and rather deeply concave almost to the base of the sclerite, but the concavity ends at the junction of the lateral carinae where the margin is rather strongly angled and blunt projections extend slightly into the depressions on either side of the raised area at the base of the abdomen.

The abdomen varies considerably in length. In its stoutest form it is no longer than the head and thorax united and hardly twice as long as its greatest width, as in *Scelionomorpha rugulosa* Dodd. At the other extreme it is much longer than the head and thorax united and three to four times as long as its greatest width, as in *Oryscelio foveatus* K., *Dicroteleia rugosa* K., *D. solitaria* Dodd, and *Xenoteleia flavipennis* Kieffer. The base is broad and not much narrower than the greatest width of the abdomen, segments 2 and 3 are almost subequal in length, each somewhat longer than 1 and 4. On the basal segment there is a broad raised median area bounded laterally by a carina or strong stria, on either side of this area the surface is depressed and may form a deep fossa against the anterior margin, the raised area is usually flat, but may form a hump or blunt prominence as in *Dicroteleia solitaria* and *Xenoteleia flavipennis* (Kieffer erroneously states that there is no basal prominence in this species), this form of the basal segment is found in *Palanteris atriclava* Kieffer and the new genus herein described as *Bracalba*.

THE SPECIES OF *ORYSCELIO*

It would seem necessary to give a list of the species that appear to belong in *Oryscelio* in accordance with the views expressed in this paper, the species appear in alphabetical order.

1 *O. acutiventris* Kieffer Philippine Islands

Trichoteleia acutiventris Kieffer, Broteria, vol 14, 1916, p. 176

Dicroteleia acutiventris Kieffer, Das Tierreich, 1926, p. 388

2 *O. atricoxa* Dodd New South Wales

Scelionomorpha atricoxa Dodd, Proc. Royal Soc. Qld., vol. 26, 1914, p. 104

3 *O. bifurcatus* Kieffer Philippine Islands

Camptoteleia bifurcata Kieffer, Broteria, vol 14, 1916, p. 172.

4. *O. brevinervis* Kieffer Philippine Islands

Camptoteleia brevinervis Kieffer, Broteria, vol 14, 1916, p. 175

5* *O. carinatus* Kieffer Philippine Islands

Camptoteleia carinata Kieffer, Insecta, vol 3, 1913, p. 387.

- 6 *O. ceylonensis* Dodd Ceylon.
Scelomorpha ceylonensis Dodd, Trans Ent Soc London, 1919,
p 349
- 7 *O. concoloripes* Dodd New South Wales
Scelomorpha concoloripes Dodd, Proc Royal Soc Qld, vol 26,
1914, p 104
- 8 *O. consobrinus* Kieffer Philippine Islands
Camptoteleia consobrina Kieffer, Broteria, vol 14, 1916, p 173
- 9 *O. crassicornis* Kieffer Philippine Islands
Camptoteleia crassicornis Kieffer, Broteria, vol 14, 1916, p 174
- 10 *O. cupularis* Kieffer Philippine Islands
Camptoteleia cupularis Kieffer, Philippine Jour Sci, vol 9, 1914,
p 298
- 11 *O. dorsalis* Kieffer Philippine Islands
Camptoteleia dorsalis Kieffer, Broteria, vol 14, 1916, p 173
- 12 *O. excavatus* Kieffer Philippine Islands
Camptoteleia excavata Kieffer, Insecta, vol 3, 1913, p 388
- 13 *O. flavipennis* Kieffer Philippine Islands
Xenoteleia flavipennis Kieffer, Insecta, vol 3, 1913, p 390
- 14 *O. flavipes* Kieffer Queensland
Scelomorpha flavipes Kieffer, Berlin Ent Zeit, vol 51, 1907,
p 296 *Psulanteris flavipes* Kieffer, Broteria, vol 14, 1916,
p 177
- 15 *O. foveatus* Kieffer Java
Zeit Hym Dipt, vol 7, 1907, p 310
- 16 *O. frontalis* Kieffer Philippine Islands
Camptoteleia frontalis Kieffer, Broteria, vol 14, 1916, p 175
- 17 *O. glabriscutellum* Dodd Queensland
Dicroteleia glabriscutellum Dodd, Proc Royal Soc Qld, vol 26,
1914, p 106
- 18 *O. grandis* Dodd Queensland
Hoploteleia grandis Dodd, Trans Royal Soc. South Aust, vol 37,
1913, p. 176
19. *O. hyalimpenus* Dodd Queensland
Scelomorpha hyalimpenus Dodd, Archiv Naturg Berlin, vol 79,
1913, p 165
- 20 *O. kiefferi* nom. nov Philippine Islands
Camptoteleia flavipennis Kieffer, Philippine Jour Sci, vol. 9,
1914. p 297.

21. *O magniclavus* Dodd New South Wales
Scelhomorpha magniclava Dodd, Proc Royal Soc Qld, vol 26,
 1914, p 103
22. *O magnus* Kieffer Philippine Islands
Camptoteleia magna Kieffer, Philippine Jour Sci, vol 9, 1914,
 p 296
23. *O marginalis* Kieffer Philippine Islands
Camptoteleia marginalis Kieffer, Broteria, vol 14, 1916, p 172
24. *O mirellus* Dodd South-west Australia
Scelhomorpha mirella Dodd, Trans Ent Soc London, 1919,
 p 349
25. *O montanus* Dodd Queensland
Scelhomorpha montana Dodd, Archiv Naturg Berlin, vol 79,
 1913, p 165
26. *O nigriclavus* Dodd New South Wales
Scelhomorpha nigriclava Dodd, Proc Royal Soc Qld, vol 26,
 1914, p 104
27. *O nigricoxa* Dodd Queensland
Scelhomorpha nigricoxa Dodd, Archiv Naturg Berlin, vol 79,
 1913, p 165
28. *O rugosus* Kieffer Java
Dicroteleia rugosa Kieffer, Notes Leyden Museum, vol 30, 1908,
 p 92
29. *O rugulosus* Dodd Queensland
Scelhomorpha rugulosa Dodd, Trans Royal Soc South Aust,
 vol 37, 1913, p 139
30. *O shakespearei* Girault Queensland
Scelio shakespearei Girault, Brisbane, private publication, 1926.
31. *O solitarius* Dodd Queensland
Dicroteleia solitaria Dodd, Proc Royal Soc Qld, vol 26, 1914,
 p 105
32. *O spinosiceps* Kieffer Philippine Islands
Psilanteris spinosiceps Kieffer, Broteria, vol 14, 1916, p 178.
Camptoteleia spinosiceps Kieffer, Das Tierreich, 1926,
 p 386

It will be observed that the genus is confined to the Indo-Malayan and Australian regions. Being well represented by species in the Philippine Islands and Australia, *Oxyscelio* is probably a dominant group throughout the Papuan and East Indian islands. The following four American species, which possess a long postmarginal vein, are excluded and their generic position is uncertain.

Oxyscelio connectens Kieffer, Ann Soc Ent France, vol 78, 1910, p 313

Oxyscelio trisulcatus Kieffer, *Chromoteleia trisulcata* Kieffer, Berlin Ent Ziet, vol 51, 1907, p 265

Dicroteleia foveatifrons Kieffer, *Prosanteris foveatifrons* Kieffer, Ann Soc Sci Brussels, vol 32, 1908, p 136

Dicroteleia carinata Ashmead, *Macroteleia carinata* Ash, Jour Linn Soc London, vol 25, 1894, p 222, *Dicroteleia carinata* (Ash) Kieffer, Das Tierreich, 1926, p 390

THE GENERIC RELATIONS OF *OXYSCELIO* KIEFFER

Oxyscelio contains medium-sized to rather large Scelionids of rather stout form and coarse sculpture. In general appearance the species resemble those of *Scelio* Latreille and *Hoploteleia* Ashmead. The relationship with *Scelio* is mainly superficial, and the two genera may be distinguished by the following characters —

Male antennae 10 jointed, propodeum without true lateral carinae, segment 1 of abdomen without a raised median area, segment 2 transversely depressed at base, forewings with the basal portion distinctly paler and with a more or less distinct stigmal spot *Scelio*

Male antennae 12 jointed, propodeum with true lateral carinae, segment 1 of abdomen with a raised median area, segment 2 not depressed at base, forewings uniformly stained, not distinctly paler at base, without a stigmal spot *Oxyscelio*

The resemblance to *Hoploteleia* is pronounced, but there are several distinguishing features, viz —

Postmarginal vein long, lateral carinae of propodeum short, posterior margin of propodeum uniformly gently concave *Hoploteleia*

Postmarginal vein absent, lateral carinae of propodeum long, posterior margin of propodeum deeply concave medially, then with a blunt projection at the junction of the lateral carinae *Oxyscelio*

As more than one species of *Oxyscelio*, namely *O. flavipes* K and *O. spinosiceps* K, have been placed by Kieffer in *Psilanteris* Kieffer, a discussion of that genus seems appropriate. *Psilanteris* was erected in 1916 with *Anteris bicolor* Kieffer (1908) as the genotype. Kieffer's description of *bicolor*, which states that the metanotum bears a spine or tooth, that the sub-marginal vein is not remote from the costa, and that segment 3 of the abdomen is as long as 1 and 2 united, represents an insect which is clearly not congeneric with the species of *Oxyscelio*. But *Psilanteris atriclava* Kieffer (1916) from the Philippines does not possess these characters, from an examination of a female cotype of this species I have made the following notes — "Resembles a small species of *Campitoleia*, but the head is much wider than the thorax; the sculpture of the head, scutum, and scutellum is coriaceous and without punctures, the metanotum is transverse, strongly foveate medially but without a produced plate, the propodeum is short, the

lateral carinae wide out from the median line, the posterior margin uniformly gently concave, venation as in *Camptoteleia*, the submarginal vein remote from the costa, the marginal vein punctiform, the postmarginal not developed, abdomen as in *Camptoteleia*, segment 2 a little longer than 1 or 3, 1 with a slightly differentiated broad, flat median area. The wide head, sculpture of head and thorax, and shape of the posterior margin of the propodeum exclude this species from *Oxyscelio*, and its generic position, as well as that of *P. atriceps* Kieffer (1918) which from the description appears closely related, is obscure.

Probably the new genus *Bracalba*, described herewith, exhibits closer affinities with *Oxyscelio* than any known genus. In both are found the raised median area on segment 1 of the abdomen, the deep median concavity and lateral projections of the posterior margin of the propodeum, and the venational character of the submarginal vein being distant from the costa. The distinguishing features may be summarised as follows —

Postmarginal vein absent, eyes bare, female antennae with a stout compact club, the sixth antennal joint much smaller than the seventh, metanotal plate usually excavated, its lateral margins not strongly oblique.

Oxyscelio.

Postmarginal vein long, eyes hairy, female antennae with the club hardly differentiated, the sixth antennal joint not smaller than the seventh, metanotal plate very large, not excavated, its lateral margins oblique.

Bracalba.

BRACALBA NEW GENUS

Chromoteleia (not Ashmead) Dodd, Trans Ent Soc London, 1919, p 329

Female Male — Medium-sized, stout-bodied, coarsely sculptured Scelionids with the habitus of *Hoploteleia* and *Oxyscelio*. Head from dorsal aspect transverse, no wider than the thorax, the vertex moderately long and sloping to the posterior border which is not margined, from lateral aspect the vertex is somewhat convex, the frons strongly convex; lower frons with a rather narrow median depression which is not margined, cheeks narrow dorsally, rather broad ventrally, eyes wide apart, large, with noticeable fine pubescence, ocelli large, wide apart, the lateral pair against the eyes. Antennae 12-jointed, in the female with a loose 7-jointed club which is scarcely wider than and hardly differentiated from the funicle, the first funicle joint long, in the male the flagellar joint except the first sub-quadrate. Thorax stout, pronotum visible laterally, its anterior angles sub-truncate, scutum large, shortly precipitous against the anterior margin which is very broadly rounded; parapechal furrows complete, foveate, scutellum large, strongly foveate against its margins, the posterior margin rimmed and broadly semi-circular, metanotum armed with a broad, coarsely sculptured lamella, two-thirds as long as the scutellum, projecting over the propodeum and extreme base of abdomen, its lateral margins oblique, its posterior margin

either gently convex or concave, propodeum short medially, long laterally, the posterior margin medially deeply concave to its base, and on either side with a blunt tooth-like projection which juts slightly into the basal depressions of the abdomen, lateral carinae of propodeum complete. Forewings long and broad, submarginal vein well-distant from the costa which it joins in a punctiform or square marginal vein, the stigmal vein very long and oblique, the postmarginal long, gradually vanishing into the costa distally but fully twice as long as the stigmal vein, basal, median, and a long radial vein indicated by brown lines. Legs normal, slender. Abdomen a little longer than the head and thorax united, broadly sessile at base, truncate or almost pointed at apex, segments 2 and 3 slightly longer than 1 or 4 segment 1 at base on either side deeply depressed so that medially there is a broad, elevated flat or humped area which in the female projects forward slightly into the concavity of the propodeum (this raised area is not bounded laterally by definite striae or carinae as in most of the species of *Oxyscelo*)

Type—*Bracalba laminata* described herewith

A genus related to *Hoploteleia* and *Oxyscelo*, the characters separating it from the latter having already been discussed, from *Hoploteleia* it differs in the form of the metanotum, propodeum, and base of the abdomen. Three species are known, two of which are described herewith

BRACALBA LAMINATA New Species

Female—Length, 4.25 mm. Black, legs, including the coxae, bright reddish yellow, antennae black, the scape reddish yellow, tegulae dusky

Head wholly strongly confluent punctate including the frontal depression, and with a pubescence of long fine pale hairs. Antennal scape moderately short and stout, twice as long as funicle 1, pedicel twice as long as its greatest width, funicle 1 elongate, two-thirds longer than the pedicel, 2 scarcely one-half as long as 1, 3 somewhat shorter than 2, quadrate, next six joints as long as wide, scarcely widened, gradually tapering to apex, the apical joint one-half longer than wide. Thorax one-fourth longer than its greatest width, pronotum and scutum strongly confluent or sub-confluent punctate and with fine pale pubescence, scutellum with large punctures which are not confluent, metanotal lamina strongly reticulate-rugose, without carinae or striae, its posterior margin gently concave medially, projections on either side of median cavity of the propodeum in the form of stout rounded teeth, the margin deeply concave between the projections and the posterior-lateral angles, the lateral carinae reaching the margin at the base of these concavities. Forewings extending to posterior margin of fourth abdominal segment, lightly stained with brown, venation fuscous. Abdomen one-fifth longer than the head and thorax united, a little more than twice as long as its greatest width, segments 1 and 4 sub-equal,

2 and 3 a little longer, 5 four-fifths as long as 4, 6 three-fifths as long as 5, its dorsal surface excavated apically so that the apical dorsal margin is deeply concave, median area on segment 1 somewhat rounded and projecting forward a little, segment 1 confluent punctate and longitudinally striate, the striæ stronger and more regular medially, 2-6 rather strongly confluent punctate with an irregular longitudinal arrangement but without defined striæ, abdomen with a short, inconspicuous pubescence which is longer laterally and on the two apical segments

Male—Length, 4 mm Differs from the female as follows—Coxæ dusky black, frontal depression deeper, scutellum confluent punctate, abdomen with seven visible segments, broadly truncate or faintly concave at apex, the apical segment short, broad, and transverse, median area of segment 1 not rounded and not projecting forward. Antennæ black, the scape red at extreme base, scape rather short and stout, pedicel short, slightly longer than its greatest width, funicle 1 twice as long as the pedicel, fully twice as long as its greatest width, 2 a little longer than wide, 3-9 quadrate, apical joint one-half longer than the penultimate

Habitat—Queensland, Gogango, 40 miles west of Rockhampton, one female, one male, in March, A. P. Dodd

Holotype and *Allotype* in the Queensland Museum (*Hy* 4177)

BRACALBA NIGRESCENS Dodd

Chromoteleia nigrescens Dodd, Trans Ent Soc London, 1919, p. 329

From the original description it is evident that this species, erected on a male from South-west Australia, is closely related to both *laminata* and *cuneata*. No comparison with the other species could be made as the holotype of *nigrescens* is in the British Museum

BRACALBA CUNEATA NEW SPECIES

Female—Length, 3.40 mm Black, legs bright reddish yellow, the coxæ dark at base, the tarsi dusky, antennæ black, the first three or four joints bright reddish yellow, tegulæ dusky yellowish

Head strongly confluent punctate and with pale pubescence, the frontal depression smooth medially. Antennal scape over twice as long as funicle 1 which is a little longer than the pedicel, the latter twice as long as its greatest width, funicle 2 as wide as long, 3 a little wider than long, next six joints a little yet distinctly wider than long, the apical joint not much longer than its greatest width. Thorax one-fifth longer than its greatest width, pronotum, scutum, and scutellum strongly confluent punctate and with fine pubescence, metanotal lamina strongly reticulate-punctate and with several obscure irregular longitudinal striæ, of which the median one projects a little at the posterior margin, posterior projections of propodeum less tooth-like

than in *laminata* and broader at apex, the posterior margin not deeply concave between the projections and the posterior-lateral angles, the lateral carinae reaching the margin at the apex of the projections. Forewings extending to posterior margin of fifth abdominal segment, lightly stained with brown, venation thick, fuscous. Abdomen one-fifth longer than the head and thorax united, somewhat more than twice as long as its greatest width, relative length of segments about as in *laminata*, segment 6 not excavated, its apical margin rounded and a little depressed, median area on segment 1 very broad, scarcely rounded, sculpture as in *laminata* except that the punctuation on segments 2-6 has a more pronounced tendency toward longitudinal arrangement and there are numerous irregular striæ.

Male --Unknown

Habitat --South Queensland, Chinchilla, three females in February and March, A. P. Dodd

Holotype in the Queensland Museum (*Hy* 1478), *Paratypes* in the author's collection

Closely related to the genotype but differing in antennal and propodeal characters

Two Interesting Queensland Eucalypts.

By W F BLAKELY (Botanic Gardens, Sydney) and C T WHITE
(Government Botanist, Brisbane)

Plate I

(Read before the Royal Society of Queensland, 28th July, 1930)

Eucalyptus Curtisi n sp

Frutex vel arbor parva 3-7 m alta, cortice levi griseo. Folia juvenilia vel primaria oblonga vel anguste lanceolata, opposita vel alterna, breviter petiolata, superne obscure viridia, inferne pallida, 2.5-7 cm longa, 0.4-1 cm lata, venis lateralibus e costa media angulo 50°-60° emergentibus. Inflorescentiæ axillares vel paniculas corymbosas terminales dispositæ, umbellis 3-6 floris, pedunculis compressis vel anguste alatis. Flores pedicellati, gemmæ 1 cm longæ, 0.5 cm. diam., tubo calycis leviter subcostato, limbo minute bidentato, operculo conico, calycis tubo brevius. Antheræ versatiles, late ovatæ vel orbiculares longitudinaliter dehiscentes. Capsulæ pedicellatæ, campanulatæ, venulosæ et subcostatæ 7-8 mm diam., disco parvo, inconspicuo, valvis 4-6 truncatis profunde inclusis.

A Mallee-like shrub or small tree 3-7 m high, with grey-silvery stems 5-8 cm in diameter. Bark smooth, leaden grey in colour, decorticating in long ribbons. Timber very pale, hard and tough. Juvenile leaves (not seen in the earliest stage) linear oblong to narrow lanceolate, opposite and alternate, shortly petiolate, dark green above, pale beneath, the margins slightly irregular and sub-revolute, 2.5-7 cm long, 0.4-1 cm broad. Mature leaves alternate or occasionally opposite, shortly petiolate, lanceolate, dark green and shining above, pale beneath, 6-13 cm long, 1.2-7 cm broad. Venation rather obscure, the lateral veins making an angle of 50°-60° to the midrib, the veinlets reticulate, intra-marginal vein remote from the edge. Inflorescence in the upper axils forming fairly large terminal corymbose panicles which become infraterminal by the time the fruit develops. Umbels 3-6 flowered, peduncles compressed or narrowly winged, 10-15 mm long. Buds conical clavate, pedicellate, pale green, 1 cm long, 5 mm in diam. at the broadest part. Calyx-tube slightly 4-ribbed or subdipterous at the base, two of the ribs more prominent than the others and terminating in rudimentary teeth on the edge of the calyx rim. Operculum conical, rather thin, pale green shaded pink, shorter than the calyx-tube. Anthers versatile, broadly ovate to orbicular, with distinct cells opening longitudinally, gland rather small, attached to the upper half of the connective. Fruit pedicellate, campanulate, venulose and faintly costate, one or two of the ribs sometimes expanded into narrow wings, 7-8 mm diam. Disc small and obscure, slightly oblique, valves 4-6, truncate, deeply enclosed.



EXPLANATION OF PLATE I
Eucalyptus Curtisi (Blakely and White)

- | | |
|---|---|
| Fig 1 Juvenile or coppice leaves, $\frac{1}{2}$ nat. size | Fig 6 Calyx tube and pistil $\times 1\frac{1}{2}$ |
| Fig 2 Flowering Twig, $\frac{1}{2}$ nat. size | Fig 7 Fruiting inflorescence, $\frac{1}{2}$ nat. size |
| Fig 3 Flower bud, $\times 1\frac{1}{2}$ | Fig 8 Capsule, nat. size |
| Fig 4 Flower $\times 1\frac{1}{2}$ | Fig 9 Seeds enlarged |
| Fig 5. Anther $\times 25$. | |

Description of Seeds—The seeds are somewhat similar to those of *Tristonia conferta* R Br, and quite distinct from any other species of *Eucalyptus*, hence a new subseries, *Leptospermæ*, is proposed

Fertile seeds pale brown, glossy, minutely rugose on the sides only, the back smooth and glossy, flask-shaped to arcuate, usually 2-ribbed, the base obtuse or produced into a small, straight point, gradually narrowed upwards into the small truncate hilum, $1\frac{1}{2}$ mm long, $\frac{1}{2}$ mm broad in the widest part. Sterile seeds somewhat similar in shape and size to the fertile seeds, but straighter and of a darker colour

Description of Seedlings—Cotyledons reniform, 5 mm long, $2\frac{1}{2}$ mm in diameter. Hypocotyl slender, terete, pale pink, 1-1.5 cm long. First pair of leaves linear-lanceolate, shortly petiolate, pale green, 1-1.5 cm long, 4-5 mm broad. Second pairs of leaves linear-lanceolate, petiolate, 1.5-2 cm long, 6-7 mm broad, dark green above, pale beneath. Third to fifth pair of leaves narrow-lanceolate, shortly petiolate, smooth, pale on the lower surface, 4-8 cm long, 0.7-1 cm broad. Sixth to eighth pair narrow-lanceolate, 7-12 cm long, 1-1.3 cm broad, the same colour as the earlier leaves. Intermediate leaves alternate, petiolate, lanceolate to obliquely lanceolate, 6-8 x 1.5-2 cm. Venation fine and somewhat obscure.

Range—Sandstone hills near Plunkett, about 33 miles S W of Brisbane (C T White, 26/8/1923 (sine No)). Bushes 6-8 ft high, bark peeling off in long strips, 24/2/29 No 5592, very common on sandstone ridges, small trees up to 7 m, but mostly smaller of Mallee-like growth, trunks with a smooth grey silvery bark, Nov 1929 (flowering specimens), D Curtis (the type)

The species is named in honour of Mr Denis Curtis, who first drew the attention of one of us (C T W) to the tree when collecting in that locality in 1923. Unfortunately, only fruiting specimens were gathered. The locality was again visited in February 1929, but again the trees were only seen in fruit, although a good series of fruiting specimens, wood, and coppice leaves were gathered. Mr Curtis, however, gathered good flowering specimens in November 1929, which enabled us to draw up a satisfactory description.

Affinities—The species closely resembles *E. Shinessii* Maiden & Blakely, in shape, colour, and general appearance of the juvenile and adult leaves, also in the shape of the buds, but the anthers place it in a different subsection, while the fruits are more venulose, and the wood is pale.

The leaves are reminiscent of those of *Tristonia laurina* R Br, and the fruits and seeds resemble the corresponding characters of *T. conferta* R Br to a marked degree.

Systematic Position—It is a very interesting species with the Mallee-like habit of *E. eudesmioides* F v M and the rudimentary toothed calyx of some of the members of the *Eudesmiæ*, but the

ring is regular, and the filaments are not tufted. The rather large terminal inflorescence is not unlike the Corymbose, but the anthers are much shorter, the fruits not urceolate, and the timber is white.

It cannot be satisfactorily placed under any of Bentham's subseries (Series Normales in the "Flora Australiensis") and a new subseries—*Leptosperma*—intermediate between the Corymbose and Eudesmies, is here proposed to receive it. The characters are as follows—

Subseries Leptosperma—Flowers rather large, inflorescences borne in the upper axils forming a terminal more or less corymbose panicle (infraterminal in fruit). Calyx ribbed, two of the ribs produced into minute teeth on the calyx rim. Capsule campanulate, seeds narrow, minutely rugose on the sides, the back smooth.

***Eucalyptus tenuipes* n. sp.**

Arbor parva vel mediocris, cortice fibrato persistenti. Folia juvenilia opposita vel alterna, linearia vel anguste lanceolata, sessilia vel breviter petiolata, folia matura vel secundaria opposita vel alterna breviter petiolata, anguste lanceolata, 6-15 cm longa et 0.8-1.8 cm lata, venis lateralibus e costa media angulo 60°-70° emergentibus, venis lateralibus et venulis subobscuris. Inflorescentiæ umbellas axillares dispositæ, umbellis 5-10 floris, pedunculis 1.2-1.7 cm longis, pedicellis tenuibus subteretibus, 0.7-1.1 cm longis. Flores ignoti. Capsulæ hemisphericæ vel late turbinate 4-5 mm diam. valvis 3-4 leviter inclusis vel discum subæquantibus.

A "Stringybark or Mahogany" of medium size, bark long-fibred, dark reddish brown, close and persistent to the small branches. Juvenile leaves not seen in the earliest stage, those available are smooth, yellowish-green when dry, opposite and alternate, linear to narrow-lanceolate, sessile to shortly petiolate, dark coloured and subcaniculate above, pale beneath, with a yellowish prominent midrib, 5-15 cm long, 0.5-1 cm broad. Mature (adult or secondary) leaves opposite and alternate, shortly petiolate, narrow-lanceolate, thin and pale, drying a dull yellowish green, 6-15 cm long, 0.8-1.8 cm broad. Venation very fine and subobscure, the lateral veins diverging at an angle of 60°-70° to the midrib, the intramarginal vein very close to the edge. Inflorescences in axillary umbels of 5-10 markedly pedicellate flowers. Peduncles slender, subangular, 1.2-1.7 cm long, pedicels very slender, subterete, 0.7-1.1 cm long. Flowers unknown. Fruit pedicellate, hemispherical to goblet-shaped, remarkably thin, 4-5 mm diam. Disc depressed or much lower than the calycine ring, rather flat, or forming a thin carnosose ring over the delicate capsule and partly concealing the three or four very small valves. Fertile seeds pale brown, D-shaped to obliquely pyramidal, glossy, faintly 2-ribbed $1\frac{1}{2} \times 1$ mm. Hilum small, terminal, irregular in shape. Sterile seeds pale brown, as long as the fertile seeds, but narrower and more irregular in shape.

Affinities.—Its affinities are firstly with *E. acuminoides* Schauer,

particularly in the venation of the leaves, shape and sculpture of the fruit, and probably in the anthers, the bark is also like that of *E acmenoides* Schauer, known in New South Wales as White Mahogany and in Queensland as Yellow Stringybark. It is, however, readily distinguished from *E acmenoides* by its narrow sub-rigid juvenile leaves, its uniformly narrower adult leaves, and in the exceedingly long slender pedicels to the fruits. *E Curtisi* Blakely & White resembles this species mainly in the narrow juvenile and adult leaves, and to some extent in the shape of the fruits, but *E Curtisi* is a smooth-barked, small, Mallee-like shrub or tree, with a large terminal inflorescence, while *E tenuipes* is a medium-sized tree with a very fibrous persistent bark.

Synonym—*E acmenoides* Schauer, var *tenuipes*, Maiden & Blakely Crit Rev Gen Euc vol vii (part lxx), p 464, plate 285, figs 5, 6

Range—Meteor Creek, South-Central Queensland, local name "Peppermint Stringybark" D. H. I. Jensen, July 1921 (type) Dalby Forest district, "Stringybark of medium size" Deputy Forester Singleton, No 34 Nudley via Dalby Forest Overseer Scouller-Chinchilla, small "Stringybark" tree of stunted appearance, very loose outside bark, 25-30 ft high, the best stem I could find was 8 inches in diameter, older trees very hollow, I only know of one patch of these trees about here, inside wood of a brown colour R. C. Beasley, No 17, 3/7/1928 Chinchilla on poor stony ground, local name "Mahogany" R. C. Beasley Additional specimens 16/1/30 (sine No.)

The Consideration of certain Factors as Potentialities in Mosquito Control in Australia.

By R HAMLYN-HARRIS, D Sc, City Entomologist, Brisbane *

Plates I-II

(Read before the Royal Society of Queensland, 1st September, 1930)

INTRODUCTION

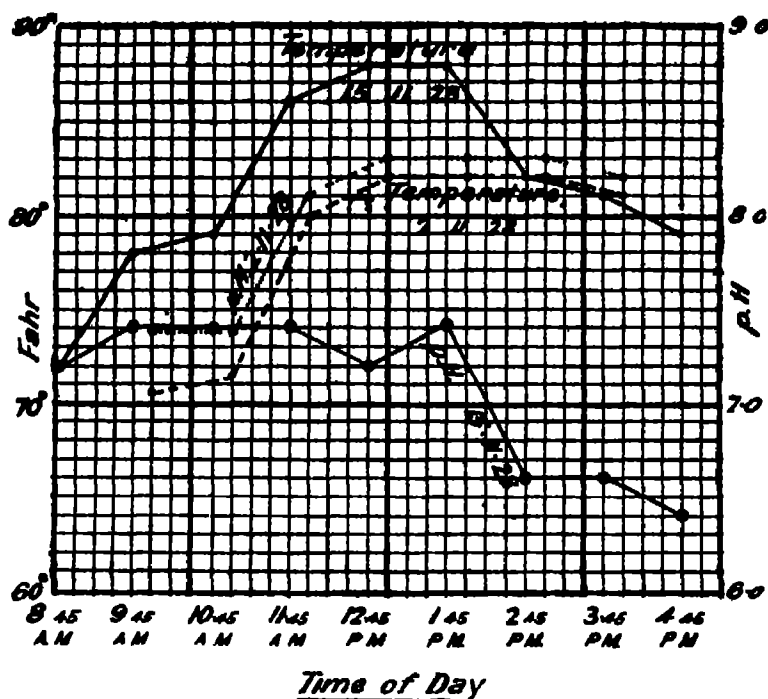
There is perhaps no phase of mosquito control less understood than that appertaining to the breeding places of mosquitoes in the open. It is commonly supposed by the average person that any and every water-holding swamp is an actual breeding place, and it is extremely difficult to bring home the actual truth with regard to this difficult question because, whilst we know that there are many that are not and never do breed mosquitoes, it is very difficult to give a correct interpretation of what is actually going on. In order to explain the position with any degree of accuracy, it has been sought to divide breeding places into places of selection as opposed to places of compulsion. The explanation as to why this should be so, however, cannot be sought by taking one factor alone into consideration, and therein lies the difficulty of the problem.

POTENTIAL *VERSUS* ACTUAL BREEDING PLACES

During fieldwork it may be possible to determine the causes of avoidance or selection with some degree of certainty in isolated instances, but unfortunately these reasons cannot be generally applied. The most obvious thing with regard to the selection of breeding places seems to be the factor of the food supply. Of recent years a good deal of attention has been given to the hydrogen ion concentration of the water, and, though these investigations have not so far yielded the results we had hoped, yet the consideration of this interesting side of the question has produced valuable scientific data (MacGregor¹⁰ and others). Records indiscriminately taken and applied without any

* From the Entomological Section, Department of Health, Brisbane City Council.

careful co-ordination tend to become useless and in some cases are grossly misleading. The hydrogen ion concentration of any given water is a useful indication of the types of waters selected by different types of mosquitoes and for this purpose alone is helpful. Hydrogen ion concentration, however, is a far more difficult thing to determine than appears at first sight, for the changes are sometimes so rapid and are influenced by so many factors that it is quite possible to take the readings of the same water at different places, at different levels, and under varying conditions of temperature and locality, and obtain different results each time, so that no useful purpose can be served by the reiteration of their values. Hydrogen ion concentration readings should be taken, therefore, with the greatest possible care, and in view of the fact that temperature has such a profound influence upon ionic dissociation, or whatever the cause may be, the temperature of the water at the very spot at which records are taken should go hand in hand. Most waters show a gradual rise in pH during the height of the sun's activities, which drops again the moment the temperature begins to fall. Some have regarded this change in pH as due to the presence of aquatic vegetation only, producing by photosynthetic activity changes in the water irrespective of temperature. This pH range can, however, be induced quite irrespective of vegetation, the change is just as pronounced and shows practically no difference from those waters which are supposed to be constantly affected by the vegetation which abounds. The way in which temperature influences the rise and fall of pH is shown by the accompanying graphs. An interesting instance of the supposed effects of aquatic vegetation upon the pH is that recorded by Matheson & Hinman¹¹ when they interpret the presence of *Chara fragilis* as giving rise to lethal effects and producing the death of mosquito larvæ, the lethal action of the plant being said to be closely associated with a high pH which varies directly with the degrees of photosynthetic activity. In Queensland *Nitella phauloteles* is said to act in a similar way, and yet, when the water is examined in which this Charophyte flourishes, the pH is shown to stand mainly in relationship to the temperature of the water, and even on the hottest day in summer this rarely exceeds 88° F or so during the peak period of the day when the highest pH is reached, with the decline of temperature the pH also declines. This plant is definitely stated to be lethal to mosquitoes, and yet throughout the greater part of November and December 1928 both *Anopheles annulipes* and *Culex annulirostris* were found thriving in thick masses of it. This does not suggest any lethal action in the field at all events.



GRAPH I—HYDROGEN ION CONCENTRATION OF "NITELLA" WATERS

The relationship of temperature and pH in a small pool with *Nitella cristata* and *Nitella phaulotoles*, illustrated by two different readings taken within a fortnight of one another at the same spot, the first on 2nd November, and the second on 15th November, 1928 (rapidly drying up) On both occasions *Anopheles annulipes* and *Culex annulirostris* were plentiful *Chara demissa* was also present in small quantities Larval destructors exceptionally numerous

It is an extraordinary thing that, however varied the readings may be, there exists some definite relationship between temperature and pH, for notice how the pH drops with the decrease in temperature Furthermore, as evidence that this pH is not induced by photosynthetic activity but is produced by the effects of temperature upon ionic dissociation, it is instructive to notice that test tubes provided with water placed in the pools from which the readings are taken will show similar differences throughout the day to those shown by the pools themselves

Enoggera Creek (5 mile radius from Brisbane Post Office)

Of greater importance, by far, than this question of pH seems to be the presence of decomposition products in the water Here we tread on surer ground, at least so it would appear, and possibly by far the greater mortality amongst mosquito larvae can be attributed to the toxic effects of these That this would prove of importance has been foreshadowed by others (Harvey¹⁷, Pruthi¹⁸, MacGregor¹⁹, Williamson²⁰) Some experiments conducted by the writer during the winter months, with a view to discovering the changes that would be likely to take place under laboratory conditions, have yielded results of scientific and practical interest

Four large glass jars holding approximately 9 or 10 litres each, to which a 25 per cent peptone solution had been added as nitrogen supply were used

OBJECT OF SUCH EXPERIMENTS

Sample 1—This experiment was conducted with the express intention of testing the effects of a well aerated peptonised solution upon mosquito larva. It was thought that a superfluity of oxygen might possibly prolong life. In order to supply oxygen to the water regularly air was bubbled through it night and morning. In other respects this jar was the same as No. 3. Both were exposed to the atmosphere.

Sample 2 was used to test the effect of a CO_2 blanket kept constantly upon the surface of the water. The air was kept excluded by means of a glass cover. CO_2 was delivered from a Kipp's apparatus night and morning.

Sample 3—This jar was left exposed to the atmospheric conditions of the room during the whole period and acted in some measure as a control.

Sample 4 was kept covered to exclude dust. Further 5 cc's were added on five different occasions making a total of 50 cc's of peptone solution during the whole period under observation. This was done to allow for the food factor. The possibility of the food supply being used up during the process of the experiment was thereby excluded.

It is however recognised that with the appearance of toxic substances as by products of putrefaction the killing power of the solution becomes apparent. It is unfortunate however that though we have every reason to believe in their presence we know so little about the nature of them.

Samples of the water as per the accompanying table were taken and subjected to analysis at intervals of about ten days attention being specially given to consideration of the nitrogen products and the changes induced therein.

Six egg rafts of (*Culex fatigans*) approximating anything from 1000 to 1500 eggs were added to each on the 27th August (1928), temperature of tap water used being in each case 67°F .

EXPERIMENTS DEALING WITH PUTREFACTION CHANGES

No of Specimens and date of collection of Water subjected to examination	pH	Free Ammonia p.p.m.	Albuminoid ammonia, p.p.m.	Nitrite p.p.m.	Nitrate, p.p.m.	Total Nitrogen	Oxygen Consumed, ml ^r in 30"
<i>Experiments</i>							
<i>Sample 1 kept well aerated throughout—</i>							
1928							
(1) September 5	8.0	2.10	2.16	0.150	0.005	4.415	7.25
(2) September 10	8.2	2.90	2.75	0.01	0.01	6.78	8.6
(3) September 25	8.0	3.40	2.34	0.01	0.05	5.80	
(4) October 31	8.4	0.8	0.0	0.012	0.16	1.412	
<i>Experiments</i>							
<i>Sample 2 with CO₂ blanket never aërated—</i>							
1928							
(1) September 5	7.0	4.40	2.26	0.187	0.005	6.852	7.5
(2) September 10	6.4	3.10	2.85	0.01	0.10	6.08	9.4
(3) September 25	6.8	6.80	2.20	0.005	0.0075	8.545	
(4) October 31	6.3	0.40	0.55	16.0	0.20	17.15	
<i>Experiments</i>							
<i>Sample 3—Normal control—</i>							
1928							
(1) September 5	8.0	3.80	2.06	0.005	0.005	5.870	7.5
(2) September 10	8.2	3.10	1.15	0.005	0.200	5.415	7.4
(3) September 25	8.4	3.44	2.40	0.0075	0.075	5.425	
(4) October 31	8.0	0.40	0.75	0.30	0.10	1.46	
<i>Experiments</i>							
<i>Sample 4—Peptone solution gradually raised by regular additions of 5 c.c. for food purposes—</i>							
1928							
(1) September 5	7.5	5.30	2.51	0.40	0.005	8.215	7.5
(2) September 10	8.0	7.80	3.45	0.0225	0.16	11.425	14.8
(3) September 25	8.4	7.94	3.8	0.087	0.16	11.847	
(4) October 31	8.3	5.4	1.05	0.030	0.050	6.520	

NOTE.—I would here like to express my gratitude to Mr W. J. Chamberlain, Water Chemist to the Brisbane City Council and the Brisbane City Council's Water and Sewerage Department, for the trouble he has taken in making the analyses above detailed.

CERTAIN FACTORS AS POTENTIALITIES IN MOSQUITO CONTROL

Time— Aug. 25, 1935, 4 p m.	PERFUMED FLUID PREPARED AND MOSQUITO EGGS ADDED			
	Sample 1	Sample 2	Sample 3	Sample 4
Aug. 28 Aug. 30 Sept. 3 Sept. 10 Sept. 14 Sept. 17 Sept. 26 Oct. 9	Eggs hatched by 2 p m. First moult 4 15 p m. Second moult Large numbers dead Third moult Conditions unaltered Still no pupae Of the original larvae only about 2 down left	A portion of eggs hatched First moult commenced (31st), numbers considerably reduced Second moult Larvae reduced, remainder well but uncomfortable Numbers considerably reduced Sign of moulting Fetid smell particularly noticeable A miserable looking pupa makes its appearance One male hatched but died soon after, only about 30 of the original larvae left	Eggs hatched out First moult Second moult Larvae well but numbers reduced Numbers of larvae dead Conditions unchanged Still no pupae 12 of the original larvae left	Eggs hatched out First moult Second moult Large numbers of larvae present, appear in a flourishing condition Larvae numerous and in a flourishing condition Larvae splendid, isolated ones growing at a rapid rate First two pupae noticed at 12 noon, first male hatched 3 p m. First female hatched 3rd October and by the 9th 4 further females and 2 males had hatched, about 200 larvae still flourishing, about Several specimens hatched, small of water like glue
Oct. 22	Only 12 larvae left, no objectionable smell noticed	Only 6 larvae left, certain protozoa very plentiful, examined dead larvae under microscope, collapse of tracheae observed Larvae dying fast One or two larvae left	6 larvae left alive, unpleasant smell	Larvae dying off About a dozen larvae still living Larvae abnormal
Oct. 27 Oct. 30	First pupa noticed Pupa died in the attempt		6 larvae left, spend all their time in gratations on the surface of the water	
Oct. 31	6 larvae and 1 pupa left, pupa motionless on the surface failed to moult		1 pupa noticed, 1 adult	
Nov. 7	One single pupa hatched out at 1 30 p m. All dead	All dead	All <i>C. fatigans</i> gone but several <i>Aedes crepusculus</i> noticed developing in this jar which had evidently been selected by them earlier in the month, when several small larvae were noticed for the first time	2 adult females dead on the top of the water, 3 dead pupae noticed, all the remainder dead
Nov. 13	All dead			

The interpretation of these results is fraught with much difficulty, but it will be recognised at a glance, however, that the mortality of the larvæ was such that very few adults matured. The peptone solution was intended to meet the food demand, and, in order to make doubly sure that there was no possibility of the larvæ dying from starvation, additional quantities of peptone were added to Sample 4 from time to time. It is interesting to note that, under such favourable conditions as at first obtained, the larvæ made rapid progress, and at the end of the first week or two, when most of the other jars were sadly depleted, Sample 4 contained by far the greater number of larvæ in a thoroughly flourishing condition. Everything seemed to go well until suddenly the larvæ commenced to disappear, and from that time on disaster after disaster overtook them.

Approximately 600 cc were abstracted from the jars each time water was taken for analysis, so that, allowing for a certain amount of evaporation, the tendency would be for each breeding place to become more restricted, including also possibly a higher concentration of the water contents.

It is difficult to explain the tremendous mortality of the larvæ in all the experimental jars except in terms of the nitrogen cycle, these facts seem to speak for themselves, forcing us to the belief that in this instance this question is of greater moment than the food supply. It certainly has proved itself to be so in the laboratory, in the field a greater number of factors are naturally brought into play, but we have no reason to believe that in the main the mortality would be any less in the field, given similar conditions, than elsewhere.

Particularly astonishing are the results recorded from Sample 2. It must occasion some surprise that the larvæ continued to live on for some time in spite of the CO₂ blanket which was never absent from the surface of the water. It may be presupposed that very little of this would enter into solution, and it is a mystery from where the larvæ procured their oxygen. The only feasible explanation seems to be that larvæ must be capable of using up dissolved oxygen from the water.

The opinion may be further expressed that the water would probably contain sufficient oxygen to enable the original larvæ to keep alive in spite of the presence of a narcotic poison, on the surface. With regard to the larvæ themselves there is a further factor to be taken into consideration besides that of oxygen, namely, the conversion of free and albuminoid ammonia into nitrite. In the proportions in which it occurs there can be little doubt that the nitrite would be toxic to mosquitoes, and the experiments tend to show that the toxicity of the decomposition products was responsible for the final debacle. Peptone is a putrefying substance, and, according to Pruthi,¹⁶ the moment the first important change causes the appearance of toxic substances, the killing time (his researches deal with fish) would only be a matter of hours.

For purposes of comparison, the following analysis of water taken from a manure pit should be studied. The liquid was a highly concentrated one and was full of all developmental stages of *C. fatigans*, hence, for the purposes intended, no more typical breeding place of this species could be imagined.

The total nitrogen is considerable, the presence of albuminoid ammonia in such quantities is evidently responsible for the existence of such an ideal breeding place in which large numbers of bacteria would swarm. The larvæ of this species seem to prefer coarse foodstuffs which insure rapid development. It is further extraordinary how consistently *Culex fatigans* selects "hay infusion" mixtures of this sort. A further interesting instance of this is often seen in the field when waterholes, hitherto free from infestation, commence to breed *Culex fatigans* freely the moment rotting grass is thrown into the water.

In such a sample as this the amount of organic matter present is not only natural but of immense value as a food reserve, and the so-called "suspended developmental phase," with which one is so familiar, seldom occurs. The significance of chloride, and total alkalinity is very imperfectly understood at present, though the high content might be a factor in the retardation of development of certain sylvan mosquitoes. No other mosquito with the possible exception of *Lutria halifazi*, which is also occasionally found in liquid manure, could exist in such concentration.

Parts per Million

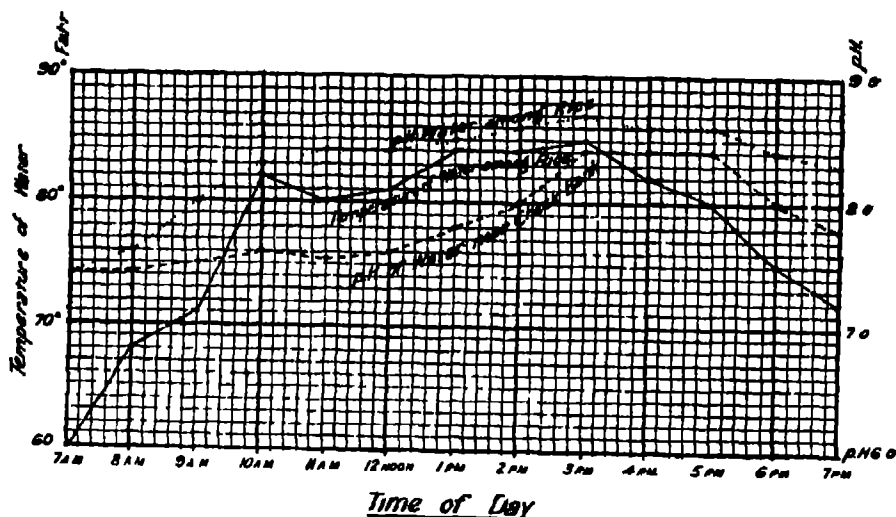
Free ammonia	25.75
Albuminoid ammonia	25.5
Nitrites	0.025
Nitrate	6
Chloride	220.0
Total alkalinity	820.0
Consumed oxygen at 212° in 30 mins	370.0
pH	7.5

HYDROGEN ION CONCENTRATION AND TEMPERATURE

Our knowledge with regard to hydrogen ion concentration and its contributing factors is undergoing many changes.

For some time past the necessity for taking readings of various waters, waters of all kinds and description, some breeding mosquitoes, some not, some containing vegetation, and some not, has been apparent. As has already been stated, the hydrogen ion concentration will vary throughout the day irrespective of the presence of aquatic life. It is a significant fact that, from the moment a peak period is reached in the temperature of the day and the temperature commences to fall, the hydrogen ion concentration of the water falls with it. It is of course not to be supposed that temperature alone is responsible, but from actual readings taken over and over again it would seem as if this were the

main determining factor That there are contributory causes must be self-evident from the variations that are liable to take place A study of the accompanying graphs should make this quite clear



(GRAPH NO. 2—HYDROGEN ION CONCENTRATION OF "RICE" WATERS)

The hydrogen ion concentration of the rice fields varies. In this instance the maximum is reached in water among the rice itself. Though the localities at which the temperature and pH were taken were only 4 yards apart, the presence of rotting sudan grass near the check bank asserted itself by influencing the pH as shown above, the pH remaining nevertheless all the time on the alkaline side of neutrality.

These readings were taken in crabhole country at Ellimo, near Yonda (Farm No. 1640, Patterson). The paddock was 5 acres in extent and the rice ten weeks old.

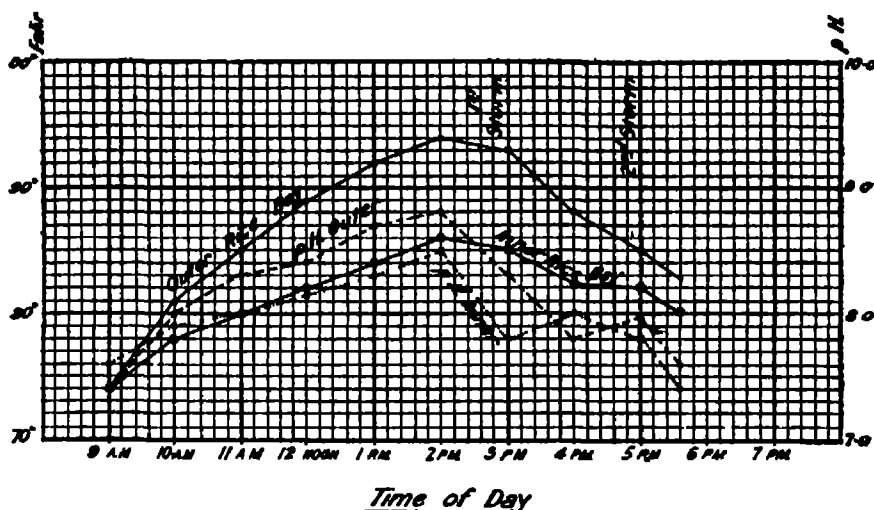
Anopheles annulipes was present along portions of the check bank in small quantities, and *Culex annulirostris* was just commencing to breed in association.

The tendency of rotting fibre to alter the pH, as is suggested by this record, opens up the question of the efficacy of such to create conditions unfavourable to mosquito breeding.

18th December, 1928—Murrool, M 1 A

In taking readings, the greatest care has been taken that the thermometer is placed in the same spot every time and that no disturbing influences are allowed to affect the water, for it is quite possible that discrepancies in some records may be attributable to disturbing elements which are apt to upset the equilibrium of the water during the course of the day. Particularly noticeable is this in Graph 3, which records happenings in one of the rice paddocks of the Yanco district, Murrumbidgee Irrigation Area, taken during a very hot spell. During the course of the day the temperature of the water rose steadily to its highest point of 95° F by 2 p.m. The pH at the same time of the day rose to 8.8, suddenly there was a change in the atmosphere and by about 2.45 p.m. a severe dust-storm had swept over the rice-fields, travelling it was estimated at a rate of about 30 miles an hour, and

the drop in the pH was exceptionally noticeable, which during that short period of time had fallen to 7.8. From that time on, the temperature continued to fall and the pH with it. At 5.30 p.m. another storm made its appearance, which necessitated retreat. A slight rise in the hydrogen ion concentration between the two storms remains unexplained.



GRAPH NO. 3—THE TEMPERATURE OF "RICE" WATERS IN ITS RELATION TO HYDROGEN ION CONCENTRATION

Temperature of pH readings taken in one rice field on each side of a check bank dividing two bays at Murrumbidgee, Farm No. 1081 (Tooth) on 7th January, (*Culex annulirostris* and *Anopheles annulipes* present in both bays. The period under review suffered two dust storms, one between 2 and 3 o'clock in the afternoon and the other after 5 o'clock, necessitating retreat, the fall in temperature and the corresponding alterations in pH are particularly noticeable. The rice crop was grown on the same chocolate soil two years running.

The difference in the temperature and pH of the two bays throughout the day is difficult to account for. Pools forming the floor of a creek bed and situated side by side all vary in the same kind of way. Such changes are not at all uncommon.

It must of course be conceded that waters taken in different parts of the rice-fields will yield slight variations of temperature as well as slight variations of pH (Graphs 2 to 4).

It is a foregone conclusion that water in the field will not have the same temperature or pH as it will have after having been brought into the laboratory, where we find the tendency is for the water to increase in alkalinity quite irrespective of any photosynthetic activity or temperature. When once the water has been brought into equilibrium with the temperature of the laboratory the water still shows a tendency to rise in pH, so that when conducting experiments in the laboratory this side of the question must not be overlooked. It is interesting to note, however, that hydrogen ion concentration seems to follow very much the same rate of development in most waters, at all events in Southern Queensland, whether provided with aquatic vegetation or not.

and, unless there is some abnormal condition responsible, the pH rarely if ever rises beyond 8.6 to 8.8, even on the hottest day in Brisbane. Where a high pH of 9.0 is reached in the field, whatever apparently the conditions may be that have induced it, mosquitoes invariably fail to select it. On investigation it nearly always transpires that the pH is due to the presence of some other factor rather than temperature, in one case, perhaps, to an increase of an alkali or some other chemical which may be present. If a weed like *Nitella phauloteles* is allowed to remain in an aquarium for a considerable length of time so that the whole jar becomes balanced, there is generally a slight variation in pH during the course of the day, and when the jar is placed during the hottest part of the day in the direct sunlight the pH rises only gradually, though many figures relating to Charophyta have been accumulated, I have never been able to get the high pH referred to by Matheson & Hinman¹¹. Furthermore it is of importance to note at times, if such a jar containing *Nitella phauloteles* placed in the laboratory is supplied with egg-rafts of *Culex fatigans*, the eggs hatch quite normally but seldom mature. This has been a source of continual worry, because the same thing happened with other Charophyta which normally in the field breed thousands of mosquitoes though perhaps a sylvan type.

Seeing that the pH reached in these jars is usually a consistent one, it was determined to test out the food factor as thoroughly as possible, and, knowing the voracity of *C. fatigans* larvæ and their preference for coarse organic substances, a fish food known as "Piscidin" was used as a supplemental food, with unexpected results, for the larvæ thrived and continued to thrive. As long as they were fed with this food every third day, the breeding cage was thronged with adults of both sexes in a shorter space of time than is usually the case. Such results proved that *Nitella phauloteles* is not lethal to mosquitoes under normal conditions, provided that the food supply is adequate to meet all larval requirements.

This is further confirmed in the field. During the recent summer of 1928, pools forming the bed of Enoggera Creek were numerous, and in these pools time after time various species of *Nitellas* had come to rest, so that the whole floor of the pools was covered from end to end and from side to side with copious growths of various Charophytes consisting of *Nitella cristata* and *Nitella phauloteles*, *Chara benthams*, *Chara australis*, and others, and in some of them several species were so entwined that it was futile to attempt to separate them. In all these pools without exception, *Anopheles annulipes* Walker occurred breeding side by side with large numbers of *Culex annulirostris* Skuse. The waters in which these plants occur are rich in iron and the deposition of iron salts is considerable, influencing to some extent the hydrogen ion concentration of the water in question, and, though iron salts in the ferrous state would seem to destroy food organisms, these sylvan mosquito larvæ seem to be in no way inconvenienced thereby.

THE WATERS OF THE RICE-FIELDS

The potentialities of the rice-fields must not be overlooked, because with the greater accumulations of water the numbers of mosquitoes will naturally tend to increase. In every part of the world where rice is grown, the carriers of malaria in particular constitute a serious menace. It is no wonder, therefore, that the numbers of *Anopheles annulipes* in the Murrumbidgee Irrigation Area should be a matter of some concern.

Breeding in the rice-fields is first induced by mosquitoes which have survived the winter in drain-ditches and such like. *As colonisation of the rice-fields must take place every year, the sources of supply from which these mosquitoes come should be regarded as the principal breeding places in the area, and control should be directed against them.* After colonisation of the rice has once taken place, breeding may go on unrestrictedly. During the period of the rice's growth the water reaches a high temperature, but, with the stooling, shade is provided and mosquito larvæ linger in the cooler portions of the rice-field. With the growth of the rice, the water becomes more and more suitable for breeding purposes. The presence of organic matter is shown by the analyses of rice-waters taken from the spot. For this reason it would appear as if the rice-paddocks in the early stages were not so suitable for larval growth, as in the latter, when the water has become suitably balanced, vegetation is plentiful, and food supplies are assured.

As the Graphs 2-4 show, rice-water is usually on the alkaline side of neutrality, probably this condition suits not only the rice best but also the organisms and bacteria which flourish therein. There has been some talk of the condition of water being affected adversely by rotting fibre (Williamson²²). So far no experiments have been made to test this possibility, though it was noticeable that in one of the rice-paddocks containing a considerable quantity of last year's rice-trash no mosquito larvæ could be located. Such a negative finding, though apparently of little value, may some day lead to more positive results. The adverse influences of toxic substances produced as by-products of putrefaction against which no mosquito larvæ can possibly hope to survive have yet to be studied. Research in mosquito eradication tends to take this direction, and, compared with the importance of this aspect of the question, the food supply sinks into mere insignificance.

Analyses of Samples of Water from the Rice-fields at Kubank's Farm, No 101, Murrumbidgee Irrigation Area —

Sample 1 — Taken from the edge of rice-field on eastern end of Farm, Mirool. Less turbid than Samples 2 and 3.

Sample 2 — Taken from drain outside check-bank on the western side of the rice-field. Sample turbid and containing green algal growths. Little movement of water in this drain.

Sample 3 — Taken from drain along road to the south of the rice-field. Little movement of water in this drain, water turbid and containing green vegetable growths.

Duplicate samples of about one litre each were taken, and the results are averages of the duplicates. No mosquitoes were breeding in any of these waters at the time.

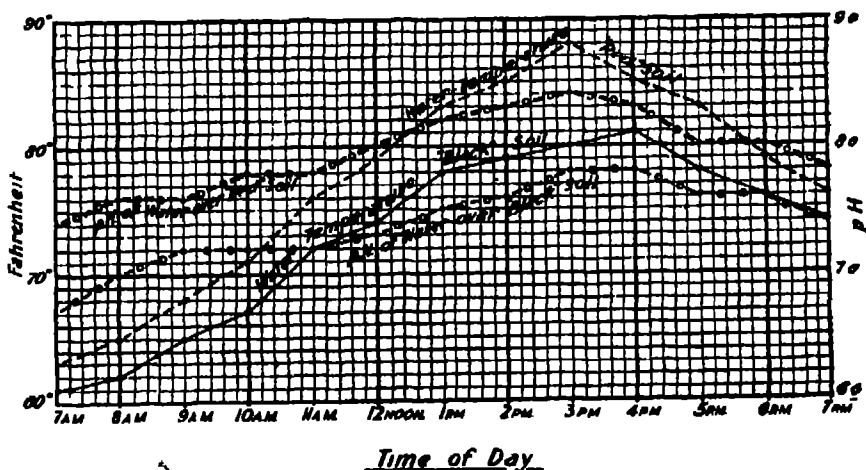
	pH	Alkalinity p.p.m. expressed as CaCO_3	Cl parts per 100,000	Oxygen consumed at 21.2° F at 30 min, parts per 100,000
Sample 1	7.2	62.0	1.22	8.31
Sample 2	8.1	60.0	1.60	10.89
Sample 3	7.5	72.2	1.62	11.33

Remarks (1) pH—These results do not give a correct idea, since the readings were determined 2½ hours after having been taken into the laboratory, so that by that time the water had come to equilibrium with the laboratory temperature, which at 3 p.m. stood at 77° F.

(2) Cl—The chlorine content of this water is low, but there is no particular reason why it should be higher than that of the water in the canal, which would be very suitable for irrigation purposes if it contained any great quantities of salts.

(3) Oxygen Consumed—These figures are higher than one is used to in ordinary waters, and can only be explained by the fact that the water had been in contact for some time with a dense rice crop, as well as a large quantity of vegetable debris, and all the samples were particularly turbid. The estimation, however, was carried out on the filtered samples.

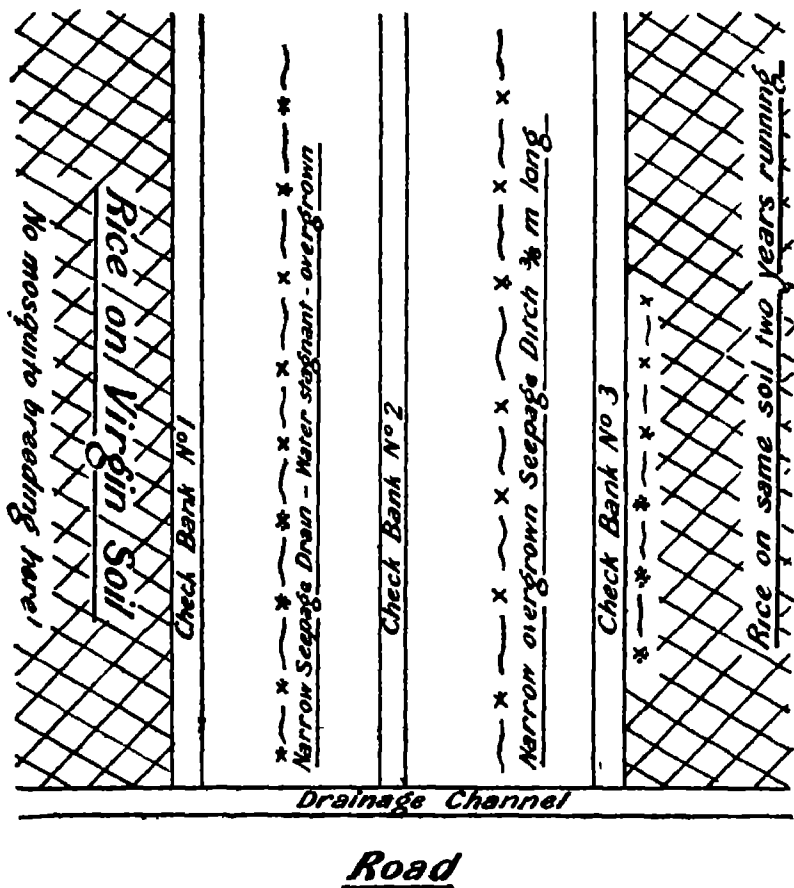
Note—My thanks are due to Mr H. Norman England, Assistant Soil Survey Chemist at the Research Station, Griffith, New South Wales, for kindly undertaking the analyses of these waters, which were made on 22nd March, 1929.



(GRAPH No. 4)

To illustrate the difference of temperature of the water and pH on "red" and "black" soils respectively, the readings taken in two adjoining rice paddocks, Farm No 1456 (Spencer), Murrumbidgee, Yanco Area, New South Wales, during 10th January, 1929. No mosquito larvae present. "Red" soils which are light, friable, and easily worked are apparently warmer than the heavier "black" soils. The "red" soil was flooded on 22nd October and the "black" soil rice paddock a week later. Both were grown on "virgin" (rice) soil.

— x — = Breeding places of *Culex annulirostris*
and *Anopheles annulipes*



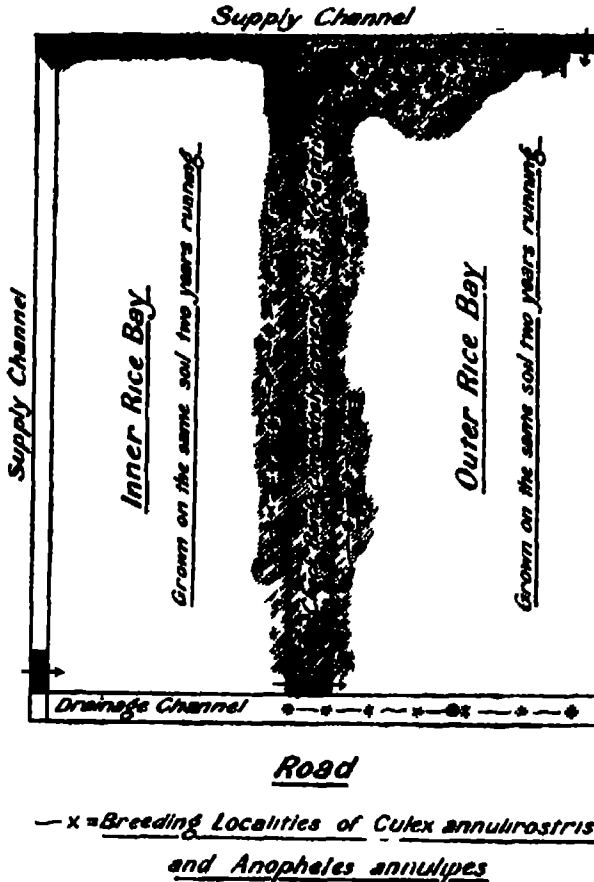
TEXT FIGURE 5—BREEDING IN NARROW SEEPAGE DRAINS

No more ideal breeding place than that here selected by *Culex annulirostris* and *Anopheles annulipes* can be imagined, the places were shallow seepage drains, the distance being a matter of 3 or 4 feet between each check bank and extending for a mile in length. The food supply consisted mainly of decaying vegetation, the attractive influence of the "hay infusion" favouring the growth both of Protozoa and Bacteria. The rice water first selected is that grown on the same soil two years running, always nearest to the source of supply.

Murrumbidgee, Yanco Area

It is significant that rice grown on the same land two years running breeds more mosquitoes than rice grown on virgin soil. This is due to the presence of much organic matter, providing considerable food supplies. In this particular instance the whole of the shaded portions were covered in vegetation consisting mainly of lucerne and several varieties of *paspalum*, and it was in the shade of these, under the protection of the bank, that larvae were found in constant association, whilst no larvae occurred at all in any part of the actual rice field. The breeding in the drain alongside was insignificant in comparison.

Locality Murrumbidgee, Yanco Area



TEXT FIGURE 6—MOSQUITO BREEDING IN THE SHELTER OF THE CHOK BANKS

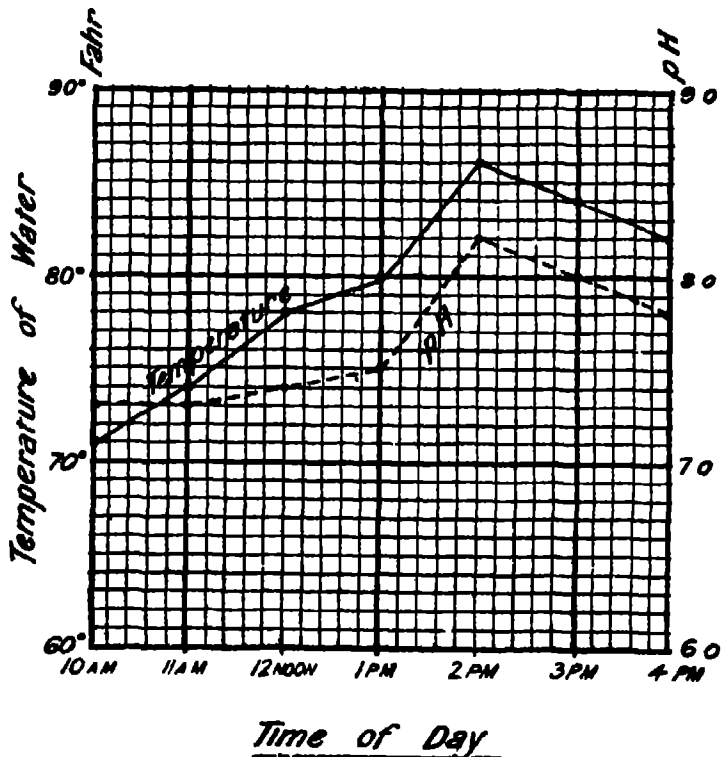
In Queensland the presence of such sylvan mosquitoes as *Culex annulirostris* and *Anopheles annulipes*, thriving among various species of *Nitella* in the field as we have seen, rules out the possibility of the Characeæ being of any practical utility.

Graphs 1, 7, and 8, illustrating the relationship of the temperature of the water and pH in pools covered with Charophytes, seem to suggest that the plant has less to do with the pH than one might be led

to suppose The graphs illustrate results obtained in pools in which two sylvan mosquitoes bred, and in which—

- (1) Different results are obtained in the same pool during the same periods of the day—on two different occasions a fortnight in between—the fauna and flora of the pool remaining relatively constant throughout (Graph 1),
- (2) *N. cristata* was alone in evidence (Graph 7),
- (3) *Nitella cristata* and *N. phauloteles* completely covered the floor of the pool, which was situated in the shade during the afternoon (Graph 8)

It is worthy of note that in all those instances investigated the pH remained fairly consistent throughout. A considerable number of readings, too numerous to publish but which show the same typical drop in pH with decrease of temperature, were taken. Not once did these particular waters record a higher pH than 8.4. This is important in view of the results obtained by Matheson & Hinman¹⁰ with *Chara fragilis*, who state that the water daily rose to a pH value of 9.0. Now



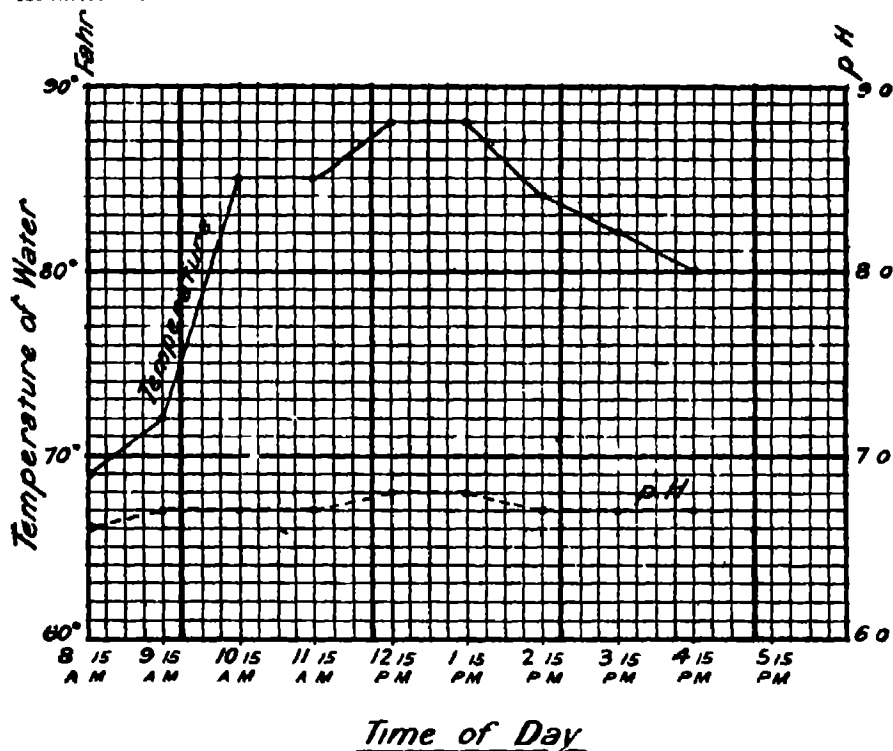
GRAPH No. 7—pH AND TEMPERATURE OF "NITELLA" WATERS

Illustrating the relationship between temperature and pH in pool, the floor of which was completely covered with *Nitella cristata*. *Anopheles annulipes* and *Culex annulirostris* occurred here in considerable numbers. The drop in temperature and pH commenced when the pool became enveloped in shade.

2nd November, 1928, Enoggera Creek (5 miles radius), Brisbane Area

in our experience a pH of 9.0 is exceptionally rare both indoors and out, in normal waters, at any time or place. When occasionally an unusual pH is found, the cause of it can usually be referred to some known factor such as the close proximity of a pool to highly alkaline soil, when artificially produced the reason of it is not far to seek.

This difference of high pH values in different countries is a puzzling one. Why *Chara fragilis* in Queensland should yield a lower pH at the maximum point of the day than the same plant does in Ithaca (U.S.A.) is not apparent unless one believes that higher latitudes and other climatic conditions exercise a distinct influence on pH.



GRAPH NO. 8—HYDROCYAN ION CONCENTRATION INDEPENDENT OF TEMPERATURE

The persistence with which the pH remains on the acid side of neutrality irrespective of temperature is evidence of the presence of another factor pulling in the opposite direction. It is suggested that the large numbers of iron bacteria growing in the water may have something to do with it.

The peak period is reached at 1:15 p.m., comparatively early in the day, accounted for by the fact that after that period the waterhole was completely enveloped in shade.

Nitella ovalata at one end and *Nitella phaeoteles* at the other completely covered the floor of this waterhole. *Culex annulirostris* and *Inophelus annulipes* were present in exceptionally large numbers in spite of the fact that the whole surface was covered with a deposit of an iron salt. *Culex annulirostris* laid egg rafts on this scum and the so called deterrent qualities of such a scum must therefore necessarily be called in question.

Brushane area

Before we can hope to apply conditions in U S A to Queensland, would it not be necessary to have some definite understanding with regard to standards needing climatic adjustments? So, for instance, the mean annual range in Ithaca (U S A) is 101° F , Brisbane, on the other hand, only has a departure from the mean temperature of a range of about 10° on either side of the mean. We in Queensland do not get such extremes as are applicable to U S A and Canada, hence the mean annual range is somewhere in the region of about 20° F.

If, therefore, the pH follows temperature, as is apparently the case judging by the evidence herein produced, then this question will prove of greater moment in our conceptions of the relativity of pH values, and considerable climatic adjustments will be necessary before the data obtained can be interpreted at their true value.

When the time arrives for this aspect of the question to be taken into consideration, it may also be found necessary to consider the effects of solar radiation upon our natural waters and on pH in particular. The results might astonish us. There is also another factor to be taken into consideration in dealing with natural control, and that is the limitations of the species itself and the various influences which contribute to such limitations.

In the absence of larval destructors, the physical environment assumes important proportions, but, although we know so little about the physico-chemical factors, their significance in natural control must be stressed. But over and above all these is the "deficiency of ability" of the mosquito to mature under certain existing environmental factors, and the greater importance of extending our knowledge in the field, rather than in the laboratory, is stressed.

SUMMARY AND CONCLUSIONS

1 It is established that mosquitoes in choosing any particular breeding-place do so for very definite reasons and not in a haphazard way, and if their love of such places as have a distinct "hay infusion" attraction can be taken seriously, then it would appear as if the food factor were really the main determining one.

2 Mosquitoes tend to breed under ideal conditions in waters best suited to their particular requirements, suitable food being the primary influence in selection. Subsequent alteration of the waters due to decomposition or other causes does not necessarily affect the choice of breeding-places, for eggs are frequently laid on waters which ultimately prove to be death-traps.

3 The economic importance of *Anopheles annulipes* is still in the balance, and it is highly desirable that its real influence upon the incidence of malaria in Australia be determined, the ideal drain-ditches of the Murrumbidgee Irrigation Area being particularly productive of larger numbers of this mosquito, the control of which is in itself only a simple matter.

4. Decomposition products in the water are of vast importance in determining the duration of the developmental stages of the larvæ and the power of the larvæ to survive in the presence of toxicity. It would seem that the presence of albuminoid ammonia insures a plentiful food supply of sorts, and renders the water particularly attractive to *Culex fatigans*

5 That larvæ can exist for an abnormal time without atmospheric oxygen is shown experimentally, since larvæ cannot exist for any length of time without oxygen, it is surmised that they are capable of making use of dissolved oxygen in the water

6 Hydrogen ion concentration varies with the temperature. the warmer the soils the higher the pH

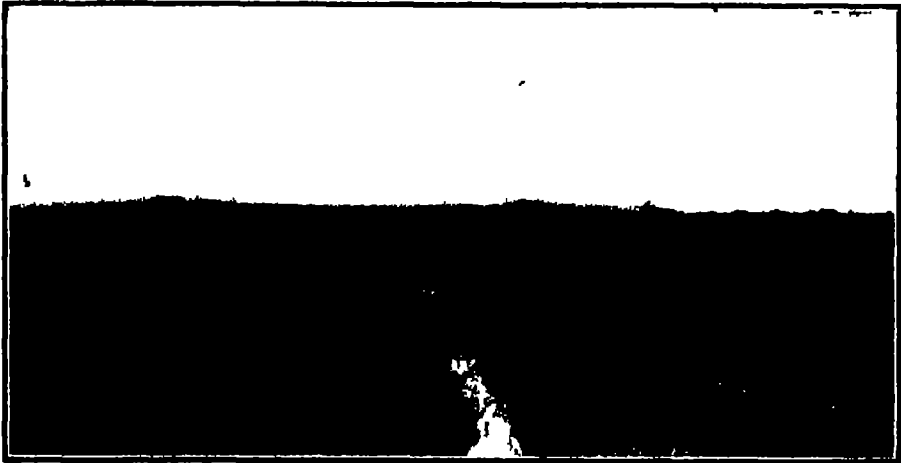
7 Characæ exert no lethal effect upon larvæ in the field. In the laboratory other factors are brought into play which equally influence waters in aquaria and other vessels, affecting the food supply so that the addition of supplemental food for larvæ induces them to select such waters, such larvæ grow and mature normally

8 The waters of the rice-fields, though conducive to breeding, are not selected at the commencement of the season. As mosquitoes are turned out of the drain-ditches and other permanent breeding-places, colonisation of the rice-fields takes place anew every year. This knowledge should provide the best means towards prevention

ACKNOWLEDGMENT—My best thanks are due to the following for their kind hospitality during my stay on the M I Area, but for them many of the observations herein recorded would have been impossible.—Mr and Mrs. Berry, Rice Farm No 1444, Bulbul, Mr and Mrs Patterson, Rice Farm No 1640, Ellimo, Yenda, Mr Harold Tooth, Rice Farm No 1081, Murrumbidgee, Yanco, Mr and Mrs O T Spencer, Farm No 1456, Murrumbidgee, Yanco

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DRAINAGE CHANNEL RUNNING OUTSIDE RICE Paddock (FARM 1444, BIRKUL, N.S.W.)

This drain receives the overflow of the rice fields and is some miles in length. During January of 1929, this ditch was responsible for innumerable numbers of *Culex annulirostris*, and to a lesser degree of *Anopheles annulipes*. As a breeding place it is ideal: the water is stagnant, and decaying vegetable matter provides necessary larval food which also consists of algae and bacteria. The whole drain is suggestive of a delightful "hay infusion," so attractive to certain types of mosquitoes, and *Laniorhynchus uniformis* taken biting at sundown on the check banks was possibly also breeding in this ditch.

It is in drains such as these that the greater bulk of mosquitoes occurring in the rice fields breed, the protection offered by the overgrown banks is sufficient for all mosquito purposes.



A NEWLY CLEANED DRAINAGE CHANNEL SHOWN BY WAY OF CONTRAST TO THE FOREGOING

Whilst the sides of the ditch are kept free from weeds, the water is confined to the centre and is in constant motion, this channel is not even a potential breeding place.

Griffith Area, N.S.W.



TWO NEWLY PLANTED RICE PADDOKS

Showing the relationship of the supply channel and seepage pools. It is mainly in the seepage that breeding is likely to occur as soon as the channels become overgrown with vegetation. The supply channels are at all times found to be free of mosquito larvae.

Mirrol Area



A RICE FIELD, 8 WEEKS OLD (NO 1444, GRIFFITH AREA)

Where readings of temperature and pH were taken throughout the course of one of the hottest days in the year (13.12.28). No mosquitoes were breeding either in the rice or in the seepage channel close by. The maximum temperature was reached at the peak period of the day (3 p.m.) in seepage water at 90° F. The readings were always taken 2 inches below the surface at the same spot in every case. In no instance did the pH rise beyond 8.6.

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- 22 SENIOR WHITE, R.—Progress towards the Realization of Biological Control of Mosquito Breeding Trans 7th Cong Far East Ass, Trop Med, 1927, ii, pp. 718-722, 7 refs Calcutta 1929
- 23 WILLIAMSON, K. B.—Mosquito Breeding and Malaria in relation to the Nitrogen Cycle Bull Ent Res, vol. xviii, pt. 1, May 1928
- 24 WILLIAMSON, K. B.—Chemical Factors in relation to Anopheline Breeding Trans 7th Cong Far East Ass Trop, 1927, ii, pp. 723-735, 3 figs, 2 refs Calcutta 1929
- 25 WRIGHT, ERNEST—On the Effects of Exposure to Raised Temperatures upon Larvae of certain British Mosquitoes Bull Ent Res, vol. xviii, part 1, pp. 91-94, Sept. 1927

The Royal Society of Queensland.

Report of the Council for 1929.

To the Members of the Royal Society of Queensland

Your Council has pleasure in submitting its Report for the year 1929

Fourteen original papers were read before the Society and published during the year. Five public meetings were held. On 9th August, Dr C M Yonge, leader, delivered a lecture, in which, with the aid of lantern slides, he described the work of the British Expedition on the Great Barrier Reef. On the 30th September, Professor E J Goddard, B A, D Sc, delivered a lecture entitled "Science and Agriculture in Java". On 8th October, Professor J A Prescott, M Sc, gave an address on "The Classification of Soils". On 22nd November, Professor Douglas Johnson delivered a lecture entitled "Studies in Shoreline Physiography". On 11th December, Professor H C Richards, D Sc, delivered a lecture, illustrated by moving films, entitled "South Africa Its Geology and Mining".

The Council wishes to acknowledge generous subsidies amounting to £142 10s from the Queensland Government towards the cost of printing the Proceedings of the Society. Appreciative acknowledgment is also made to the University of Queensland for housing the library and providing accommodation for meetings. Dr J V Duhig very generously donated £15 for the binding of certain valuable periodicals.

The membership roll consists of 4 corresponding members, 7 life members, and 164 ordinary members. During the year there were 10 resignations, and 7 new members were elected. Mr H Tryon was elected a life member of the Society.

There were ten meetings of the Council, the attendance being as follows — E W Bick 8, W H Bryan 9, W D Francis 4 (granted leave of absence 31st October, 1929), C D Gillies 0 (resigned 31st October, 1929), G H Hardy 2 (elected 31st October, 1929), R W Hawken 4, J B Henderson 6, D A Herbert 9, T G Jones 7, H A Longman 3, J P Lowson 6, E O Marks 3 (elected 3rd October, 1929), T Parnell 4, F A Perkins 9, R Veitch 6.

J P LOWSON, President

F A PERKINS, Hon Secretary

THE ROYAL SOCIETY OF QUEENSLAND

Dr.

STATEMENT OF RECEIPTS AND EXPENDITURE FOR YEAR ENDING 31st DECEMBER, 1929

3c

RECEIPTS	£	s	d	EXPENDITURE	£	s	d
Bank Balance, 31st December, 1928	25	4	2	Government Printer Volume and Abstracts	285	9	0
Subscriptions	152	15	6	Hon Secretary (Postages and Petty Cash)	15	12	5
Government Subsidy on cost of Printing	142	10	0	Hon Treasurer (Postages and Petty Cash)	2	0	0
Sale of Reprints and Volumes	20	12	0	Hon Librarian (Postages)	1	0	0
Donation to Library Bookbinding (Account, Dr J V Dubig)	15	0	0	Hire of Cinematograph	2	0	0
Exchanges	0	0	0	Lanternists	3	0	0
				Advertising Lectures	1	14	0
				State Government Insurance	0	13	0
				Bank Charges	0	10	0
				Exchanges	0	7	8
				Cheque 'B 976134', not presented at 31st December, 1929	15	0	0
				Balance in Q N Bank, 31st December, 1929	29	1	7
					£356	7	8

Examined and found correct

H J PRIESTLEY, Hon Auditor

E W BICK, Hon Treasurer

ABSTRACT OF PROCEEDINGS, 31ST MARCH, 1930

The Annual Meeting of the Society was held in the Geology Lecture Theatre of the University at 8 p.m. on Monday, 31st March, 1930. The President, Professor J. P. Lowson occupied the chair and about sixty members and visitors were present. An apology for absence was received from Miss Bage. The minutes of the previous meeting were read and confirmed. The Annual Report and Balance sheet were adopted.

The following officers were elected for 1930 —

President Mr J. B. Henderson, F.I.C.

Vice Presidents Prof J. P. Lowson, M.A., M.D. (*ex officio*) and Dr D. A. Herbert

Hon. Secretary Mr F. A. Perkins, B.Sc. Agr.

Hon. Librarian Mr W. D. Francis

Hon. Treasurer Mr E. W. Bick

Hon. Editors Mr H. A. Longman, F.L.S., C.M.Z.S., and Dr W. H. Bryan, M.C.

Hon. Auditor Prof H. J. Priestley, M.A.

Members of Council Dr R. W. Cilento, Dr T. G. H. Jones, Mr J. A. Just, M.I.M.E., Prof H. C. Richards D.Sc., and Mr C. T. White, F.L.S.

The following were proposed for ordinary membership — Mr A. J. Stoney, B.E.E., proposed by Dr Herbert and Mr Perkins, Dr J. M. Roe, proposed by Mr Buhot and Mr Perkins, Mr E. M. Shepherd, B.E., proposed by Mr. E. J. Wood and Mr Perkins. Messrs D. O. Atherton and H. K. Lewcock, M.Sc., were unanimously elected ordinary members of the Society.

The President moved and Prof Richards seconded the following motion, which was carried unanimously — "That a message be sent to Sir Douglas Mawson, Capt Davis Prof Harvey Johnston, and the rest of their party congratulating them on their safe return, and the wonderful work achieved."

Prof J. P. Lowson delivered his Presidential Address, entitled 'Recent Psychology'. On the motion of Prof Goddard, seconded by Prof Scott Fletcher, a vote of thanks was accorded the retiring President for his address. Prof H. C. Richards and Mr H. A. Longman expressed the Society's appreciation of the presence of His Excellency the Governor.

SUMMARY OF PRESIDENTIAL ADDRESS.

The main subject of the address is the repetition of the past in the present in our mental life.

The repetition of the past in the present is a universal characteristic of mental process. It is not confined to conscious memory, but is true of all our perceptions, thoughts, and actions. We can perceive only

what we have learned to perceive and analysis and experiment show that the greater part even of our external experience comes from within, although it seems to us to come from without. The human mind is somewhat like a magic lantern. Consciousness is the screen on which our experience appears. But it is lit up from two sides at once, from within as well as from without. Our experience is a compound of pictures thrown from within out of the past with pictures thrown from without out of the present (through the senses), but the two harmonise so beautifully that we cannot distinguish them. In nervous breakdown, however, and still more in insanity, the inner and the outer pictures may clash and their opposite origin becomes apparent.

An important step forward in recent psychology has been the recognition of the fact that the principle of unconscious repetition of the past in the present, which makes possible the growth of every kind of knowledge and practical skill, is equally true of our emotional growth and development. Just as little in the emotional sphere as in the sphere of knowledge and action do new ways of feeling come into being out of nothing and without relation to the past. Our emotional life consists in fact very largely of the repetition in the present of emotional responses, the true origin of which is to be found in our past. It is, for example, a mistake to suppose that the disadvantageous peculiarities of character and feeling from which so many of us suffer are always inborn disadvantages. They are just as likely to be acquisitions made in those earliest years of our life which we have forgotten, and fixed by the repetition of the past which our mental constitution tends to force on us. The same is naturally true of advantageous qualities and feelings also. What we find in practice is that modes of emotional response (love, hatred, and the like) called out in the earliest years of life, tend to persist as part of the apparently fixed character of the individual. This is a fact of very great social importance, since it opens up the possibility of a form of social culture hitherto neglected. Moral education has usually taken the form of enforcing the acceptance of certain ideas and certain forms of conduct without much regard to the nature of the motives which actually induce the child to accept them. The result has often been to cripple rather than further emotional growth. We now recognise that a child's emotional and moral inheritance cannot be expected to unfold and develop normally in unsuitable conditions any more than a plant will develop normally in the absence of sunlight, air, and suitable soil.

Passing now to psychoanalysis -- The practice of psychoanalysis introduced by Professor Freud, of Vienna, has thrown the facts just mentioned about our emotional life into sharp relief, but psychoanalysis has also made special contributions of its own which reinforce the importance of these facts. Fifty years ago another Viennese physician, Josef Breuer, made the discovery that consciousness does not necessarily accompany our mental processes. Under certain circumstances particular experiences lost to conscious memory may nevertheless persist

unconsciously and exert a powerful and irrational influence over subsequent emotional life. Shell-shock during the war furnished many illustrations of this. Thus the idea of unconscious mental process under repression came into being, one character of such process being the compulsive repetition of past emotion, not in harmony with, but in defiance of, reason and the present.

It was this observation of Breuer's which, in the hands of Professor Freud, led to the gradual development of the modern psychoanalytic method. The value of the method itself is not seriously disputed, but the results attained by its use have been the subject of much dispute. It is often argued, for example, that they are exaggerated. My own experience leads me to believe that the acceptance of the main position actually held by Freud is only a matter of time, but I must confine myself to a single central feature of it.

Analytic investigation appears to show (in conformity with what I have said above) that the first appearances of altruistic feeling in infancy—that is to say, the first affection felt towards a fellow creature clearly distinguished from the infant himself—constitutes a cardinal step in emotional development, since the feelings then called out form the germ out of which all later social affections will have to develop. Hence it is of the greatest importance that this particular step in development should go forward normally. But at the same time that this became apparent a further most important fact appeared also. Our earliest affections are not only the germ of later social feeling, they contain also the immature but powerful determinants of later sexuality. This close association between the first appearances of sexual feeling and the first appearance of affection in the wider sense is not very surprising, since it is paralleled by other features of our development, but it is naturally somewhat repugnant from the adult point of view, since the earliest affections of an infant are naturally directed towards those who stand nearest to it—that is, towards the nearest members of its own family. The situation is further complicated by the fact that most of the manifestations of sexuality in infancy undergo repression (in the technical sense) at the commencement of childhood proper. Apart from analysis they remain excluded from conscious memory. Nevertheless, the influence which they may exert on the sexual life of the individual at adolescence and subsequently is sometimes of the last importance. Many sexual abnormalities find here their explanation, in the compulsive and irrational force exerted by infantile repressed experience. On both these counts then—social and sexual—we hold that infantile experience is the most powerful and important determinant of adult life and character.

ABSTRACT OF PROCEEDINGS, 28TH APRIL, 1930

The Ordinary Monthly Meeting was held in the Geology Lecture Theatre of the University on Monday, 28th April, at 8 p.m. Dr Herbert in the chair, and about twenty-five members present. Apologies for absence were received from Messrs Henderson and Lewcock. The minutes of the previous meeting were read and confirmed. The following were proposed for ordinary membership — Messrs E. A. O'Connor, M.Sc., and M. White, M.Sc., proposed by Dr Jones and Mr Perkins, Dr W. H. Steel, proposed by Mr Perkins and Prof. Lawson. Misses F. E. Scott and E. M. Ferricks were proposed for associate membership by Messrs Perkins and Cayzer. Messrs A. J. Stoney, B.E.E., and E. M. Shepherd and Dr J. M. Roe were unanimously elected ordinary members of the Society.

Mr H. A. Longman exhibited two somewhat abraded otoliths of a freshwater catfish, *Tandanus* sp., which had been found in alluvium at Lake's Creek, Rockhampton, by Mr F. Jardine, who had sent them to the Queensland Museum. Generic identification was established by direct comparison with otoliths or "ear-stones" taken from recently captured catfishes.

Dr E. O. Marks exhibited the anterior half of a stone axe, found near the junction of Ewen Creek and Stanley River, near Peachester. The cutting edge had been fashioned entirely by chipping. This exhibit was commented on by Mr Longman.

Dr W. H. Bryan read extracts from a paper by E. C. Tommerup, B.Sc., A.A.C., entitled "A Geological Reconnaissance of the Linville-Nanango District."

This paper deals with the geology of a large area situated between Linville and Nanango, Queensland, the information being gathered during numerous journeys made by the writer while engaged in making traverses of the district as an officer of the Queensland Forest Service.

The writer has attempted to correlate and classify the various rock formations of the district, but does not regard the classification as either complete or final.

The oldest rocks in the area are representatives of the Brisbane Schists which occur between Yarraman and Wondai. Next in succession (between Yarraman and Esk) there are several outcrops of slates which probably belong to the Gympie Series. Whether these were deposited *in situ* or were faulted into their present positions is not clear.

These were followed by the Andesitic Stage of the Esk Series, which is typically developed near Marbletop, east of Nanango. The writer was able to follow the massive andesites and andesitic

agglomerates of this stage from Goomeri to the head of the Brisbane River and beyond Mount Stanley at least as far as the junction of Avoca Creek with the Brisbane River

The overlying Shale Stage of the Esk Series was examined by the writer at a number of different localities within the area described, among them being Upper Yarraman Creek, where a small seam of coal is included in the section. Many of the conglomerates associated with the shales contain numerous pebbles of milky quartz, jaspers, and other representatives of the Brisbane Schists, together with others, derived apparently from the Gympie Slates

The igneous rocks of the area fall naturally into three groups—viz (a) Granodiorites, (b) Porphyrites, (c) Basalts. The granodiorites are younger than the Gympie Series, which they intrude, but are older than the overlying Esk Series. The age of the porphyrite intrusions is not clear. They are apparently closely associated with the granodiorites, although they are probably somewhat older. On the other hand, they may possibly prove to be related to the Andesitic Stage, which is restricted to the eastern part of the area. The basalts outcrop along the Cooyar Range and elsewhere, and overlie the Shale Stage of the Esk Series

The paper is illustrated by a sketch-section from Tarong to Taromeo, and by geological and contour sketch maps

Miss Dorothy Hill, M Sc, read a paper entitled "The Development of the Esk Series between Esk and Lunville, with Reference to the Possible Occurrence of Workable Coal"

In the Brisbane Valley, between Esk and Lunville, a series of Triassic rocks is trough faulted along the north-westerly grain of the country into the Palæozoic (including Permo-Carboniferous) formations. These Triassic rocks, the Esk Series, are freshwater basin deposits laid down by rapidly changing currents, with intensive contemporaneous volcanic activity. The Lower Esk Series is typified by very intense andesitic activity, with the formation of a great thickness of peculiar andesitic boulder beds, with sedimentary deposits being formed during periods of temporary cessation of volcanic activity. The strictly conformable Upper Esk Series, however, is typified by a thick development of rapidly varying sedimentary deposits, with interbedded flows and tuffs resultant from intermittent trachytic activity. Above the Upper Esk Series the Bundamba sandstones, now all eroded away except from the southern part of the area west of Esk, were deposited without angular unconformity

In addition to the trough faulting, the Esk Series has been strongly affected by sharp north-westerly directed anticlinal fracturing, accompanied by the intrusion of an important series of hypabyssal rocks, the Brisbane Valley Porphyrites, closely related in mineralogical type to the flows and tuffs of the period of sedimentation. The time relations of the trough faulting and anticlinal fracturing are

unknown, but they both occurred before the extrusion of the Tertiary rhyolites.

The conditions of deposition and the type of folding of the Eak Series do not promise well for the occurrence of a large field of workable coal, but some of the synclinal areas are worth more detailed mapping on the chance of the discovery of a deposit large enough to support a small colliery

These papers were discussed by Prof Richards, Drs Bryan, Whitehouse, and Marks, and Messrs Denmead, Bennett, and Dunstan

A paper, "Essential Oils from the Queensland Flora, Part 1, *Baccharis virgata*," by T G H Jones, D Sc., and M White, M Sc., was laid on the table

1,560 ccs of oil, representing a yield of 88 per cent, were distilled from 353 lb of the leaves. The constants recorded for the oil are—
 $[d]_D^{20} = +16.5$, $N_D^{20} = 1.4742$, Acetyl No = 41, Ester No = Nil,
 Density = 0.921

Examination of the oil showed the presence of α -pinene 50-60%, cineol 30%, with pino-carveol, aromadendrene and a sesquiterpene alcohol in smaller quantities.

Prof H C Richards communicated a short paper, "A Record of Graptolites from Mount Isa," by R A Keble

A sample of fine, thinly-bedded sandstone with some of the laminations completely silicified and showing galena, and with some of the others more or less stained with ferric oxide, was found last summer on a spoil dump at Mount Isa by Mr J O'M Lyons, and was subsequently handed to Mr R A Keble by Mr E Broadhurst

Mr Keble regards the face of the specimen as showing graptolites preserved either as impressions or as films light-red in colour

There are about fifty polyparies in all, poorly preserved, but many showing both proximal and distal extremities, and one or two showing thecal details

They all belong to the Monograptids, and, although absolute specific determination is unwise, Mr Keble has no hesitation in citing *Monograptus cf hallyi* Barr and *Monograptus cf undulatus* E and W

On this evidence he regards the age of the Mount Isa beds as being Silurian, and mentions that *M cf hallyi* occurs in shale approximately 1,000 feet above the base of the Silurian in Victoria at Jackson's Creek and on the Wood's Point Goldfield. He also regards the European equivalent of the Mount Isa beds as approximately zone 21 near the top of the Llandovery

Especially since the finding of the Cambrian trilobites at the Templeton River the Mount Isa beds have been regarded very

generally as Pre-Cambrian in age. On this account, and owing to the association of ore-bodies of much importance, the determination is of considerable interest.

In communicating the paper Professor Richards summarised the evidence for the existing general idea as to the Pre Cambrian age of the Mount Isa beds, and especially considered the relationship between these steeply dipping beds and the gently undulating fine grits of Middle Cambrian age at the Templeton River a few miles to the west of Mount Isa.

The results of the traverses made by Messrs Shepherd and Ridgway, of the Queensland Geological Survey, and of Mr J B Wadley in the same region were considered, and possible interpretations of these in terms of a Silurian age for the steeply inclined Mount Isa beds were put forward.

Considerable discussion took place, and general disagreement with the determination of the specimen as graptolitic in character was expressed by several members, especially Dr F W Whitehouse, Mr B Dunstan, and Mr E C Saint Smith.

The firstnamed considered the specimen organic, but he could not believe it to be a graptolite, particularly a species of *Monograptus*. Messrs Dunstan and Saint-Smith regarded the specimen as purely inorganic, and pointed out that much search had been made for graptolites and other fossils at Mount Isa, and, although material similar to the specimen under discussion had been seen, the structures were considered to be purely inorganic.

ABSTRACT OF PROCEEDINGS, 26TH MAY, 1930

The Ordinary Monthly Meeting was held in the Geology Lecture Theatre of the University on Monday, 26th May, at 8 p.m., the President, Mr J B Henderson, in the chair, and about twenty-five members present. An apology for absence was received from Miss Holdsworth. The following visitors were also present—Professor Sir T W Edgeworth David, Professor E W Skeats, Dr P Marshall, Dr L K Ward, Dr C Fenner, Mr J F Bailey, and Professor Sumner. The minutes of the previous meeting were read and confirmed. The following were proposed for ordinary membership—Mr F Barker (proposed by Messrs Watkins and Hedsman) and Mr J B Wadley (proposed by Dr Marks and Mr Perkins). The following were unanimously elected members of the Society—Misses E M Ferricks and F E Scott, Dr W H Steel, and Messrs E A O'Connor and M White.

Mr C T White exhibited a specimen of the fruit of *Parinarium laurinum* A. Gray picked up on the beach at the southern end of Moreton Bay by Mr Denis Curtis. Fruits of this tree, which is a native of the Solomon Islands and New Guinea, are sometimes picked up on the Queensland beaches, but the species so far as known has not yet succeeded in establishing itself here.

Dr E O Marks read a paper entitled "The Physiographical Significance and Non-Migration of Divides"

Where, owing to comparative shortness or other denudational advantage, one stream is more active than its neighbour, it will erode its basin more rapidly and encroach on the neighbouring basin. This shifting of the divide, known as migration or headward erosion, is generally recognised as a very active physiographical principle, and on it is based the theories of river-capture and rearrangement of drainage which figure largely in modern physiography.

In this paper it is pointed out that, according to the theory, any originally straight divide must be made crooked by the irregular action of this headward encroachment. Consequently any straight divide must have a tectonic origin and still be in its original position.

The Blackall-D'Aguiar ranges form such a straight divide, separating the group of numerous short streams running eastwards into the sea from the headwaters of the Stanley and Mary rivers. On Mount Mec and Blackall tablelands the divide is at 1,500 feet elevation, but for 10 miles between these is about 500 feet. Here the rocks are soft and differential denudation obviously accounts for the lower elevation and different character of this part of the divide. Although the short streams have courses entirely on soft sandstone country, while the Stanley waters have 180 miles to go largely over hard rocks, and although there is clear evidence of the lowering of this part of the divide by denudation at least 1,000 feet there has been no migration, and this in a situation where it would necessarily have occurred had the theory been correct.

Other straight divides confirm this absence of migration in situations where the theory would require it, except to such a minor degree as to render it utterly incapable of the results claimed for it.

It is necessary, therefore, that all that part of physiographical theory depending on the migration must be seriously modified if not entirely discarded.

Some inquiry is made to discover the flaw which renders the theory inconsistent with the observed results of these nature-performed experiments.

This paper was discussed by Professor Sir Edgeworth David, Dis Ward, Fanner, Marshall, and Bryan, and Messrs Bennett and Jones.

Mr Perkins read extracts from a paper by B B Grey entitled "Chaetognatha from the Society Islands."

The *Chaetognatha* discussed in this paper were collected in sixteen hauls, irregularly spaced over a period of twelve months. Ten species are represented, belonging to two genera, *Sagitta* and *Pterosagitta*, including *S. occana* n. sp. A table illustrating the coincident occurrence of the species is included. *Sagitta oceania* n. sp. is described as new to science, the description being supplemented by several text figures. The

fertilisation of the *Chaetognatha* is discussed, special reference being made to observations on *S. oceanica* and *S. enflata*. A brief account is given of the parasites found in four species of *Sagitta*. A meal taken by *S. enflata* is described in detail, the meal being a specimen of *S. fridrici*.

The following paper was laid on the table — "Essential Oils from the Queensland Flora, Part 2, *Agonis abnormis*," by T G H Jones, D Sc, and M White, M Sc

Examination of the essential oil obtained from the leaves of *Agonis abnormis* (yield 6 per cent) has shown that it possesses the following constants —

d_{15}^4 , 9040, n_D^{20} , 1.4905, $[\alpha]_D^{20}$, + 9, Ester number 74, Acetyl value 16, Acid number 17, and is composed of a mixture of α pinene 90%, aromadendrene 60%, and a small percentage of sesquiterpene alcohols. The aromadendrene fraction is being further examined and at least two sesquiterpenes are present

ABSTRACT OF PROCEEDINGS, 30TH JUNE, 1930

The Ordinary Monthly Meeting was held in the Geology Lecture Theatre of the University on Monday, 30th June, at 8 p.m. The President, Mr J B Henderson, in the chair, and about twenty members present. The minutes of the previous meeting were read and confirmed. Messrs F Barker and J B Wadley were unanimously elected members of the Society.

A paper, entitled "The Genus *Oryscelio* Its Synonymy and Species, with the Description of One New Genus," by Mr A P Dodd, was laid on the table.

This paper discusses the characters of the Scelionid genus *Oryscelio* Kieffer, erected with *O. foveatus* Kieffer from Java as the genotype. The genera *Camptoteleia* Kieffer, *Durotelia* Kieffer, and *Xenoteleia* Kieffer are regarded as synonyms of *Oryscelio*, the reasons for making these alterations being given at length. Many species originally described or formerly placed in the genera *Scelionomorpha* Ashmead, *Hoploteleia* Ashmead, *Psilanteris* Kieffer, and *Scelio* Latreille are transferred to *Oryscelio*, which will now contain 32 listed species from Ceylon, the Philippine Islands, Java, and Australia.

The characters of *Oryscelio* are compared with those of related genera. A new genus, *Bracalba*, is erected to contain *Chromoteleia nigrescens* Dodd and two new species, *Bracalba laminata* and *B. cuneata*, all from Australia, *B. laminata* being selected as the genotype.

Dr L S Bagster conducted some very interesting experiments with liquid air, and showed a metallic spectrum on the lantern screen.

Mr E J Wood, M Sc, exhibited specimens of the following diseases of sugar-cane from the collection of the Bureau of Sugar Experiment Stations — (1) Physiological Chlorosis (deficiency), banded chlorosis (the effect of cold moist nights) (2) Virus Two specimens showing Mosaic (Fiji) disease, which, though not shown by the experimenter to be transmitted by inoculation or by insects, has X bodies which seem to indicate its virus nature Dwarfing is a disease which seems to be new to science It has not been reported from any other country, and 66 stools of it are known It resembles Fiji disease in its symptoms, except that the galls are replaced by chlorotic areas somewhat similar to Mosaic It is a phloem disease and is transmissible through cuts, as has been proved by the writer, who is at present working on the etiology of the disease Its symptoms suggest a virus disease, but artificial inoculations have not yet succeeded (3) Bacterial Gumming (*Bacterium vasculare*), Leaf Scald (*B. albilineans*), and Top Rot, a bacterial disease not confined to the vascular tissue (4) Fungal Downy Mildew (*Sclerospora sacchari*), Pokkah Boeng, and Knife Cut (presumably *Fusarium moniliforme*) A number of root diseases of fungal origin were exhibited Peg Leg is a butt infection of the Bundaberg-Childers areas and clayey Mackay soils *Schizophyllum commune* is a secondary parasite of little importance (5) Phanerogamic Parasites *Striga* spp, which are short lived, flourishing from December to February (6) Teratological Heavy Root, a rare abnormality

Dr D A Herbert exhibited (1) Haustoria of *Ola retusa*, a phanerogamic parasite attacking *Gahnia* sp, the haustoria were the size of a pinhead, and were collected at Burleigh, June, 1930 (2) A French bean seed with two embryos (3) *Phragmidium disciflorum*, a rust of the rose on the variety Star of Queensland (uredospore stage) (4) A section of a stem of a liana, *Vitis acetosa*, with exceptionally long and wide vessels

On behalf of Mr E C Tommerup, B Sc, specimens were exhibited of Hoop Pine (*Araucaria Cunninghamii*) showing heart girdling, which he has investigated in conjunction with Mr R B Morwood, M Sc. The stem and crown die, the roots remain vigorous and often throw off coppice leaves at ground level At the ground level, however, a collar-like constriction is formed, and though the bark is unbroken the water supply is evidently cut off and the tree dies Plantation trees of two or three years' establishment may be affected The girdle is often associated with slight swellings above and below the constriction, when the bark is peeled away, dark necrotic rings may be seen above and below the lesion This disease has been reported from Reserve 151 Neungma in the Bunya Mountains Area, and from Reserve 220 Kilkivan Both these areas are on the ecological limit of the rain forests and only receive about 35 inches of rain per annum, with a mean summer temperature of approximately 80 deg F Although Bunya Mountains area is one in which the pines are frequently affected by fungal growths, it is considered that this condition exists because the trees are struggling for a living and are more susceptible to fungal attack than are vigorous trees,

rather than that the meteorological conditions of this locality are favourable to fungal incubation. The plants attacked are nearly always in exposed situations on heavy soil. Several possible factors were considered, such as wind, damping, fungus, insect injury, frost, &c, but it was eventually decided that it was primarily due to the heating effect of the soil when exposed directly to the sun's rays. Similar diseases are recorded from U S A with other conifers.

Dr J V Duhig, on behalf of Professor Goddard and himself, showed two fish of the species *Galarias o'connors* (Ogilvy) which had suffered from melanosis. Dr Duhig showed lantern slides of sections of the skin of the fish. The pigmentation was shown to be due to heavy deposits of what is believed to be melanin about the walls of rounded or oval sub-epithelial cysts, which are lined with epithelium and are, in reality, processes budded off from the skin epithelium. Another section showed these cysts to contain a parasite, which Dr Goddard stated to be the metacercaria stage of a trematode, (*Monorchis* (?) species). A section was shown demonstrating the ventral sucker by which the genus could be identified. The fish is the second intermediate host of the parasite and the authors propose to continue their investigations in the direction of feeding experiments in order to secure the adult worm. To this end they desire specimens of sick fish which are well pigmented. The exhibit had a double interest, in that it raised the problem of melanin production and the subject of the exhibit was an indigenous species to which little attention had been paid.

Mr C T White exhibited specimens of *Datura ferox* Linn from Clermont, Central Queensland. The species, which is supposed to be a native of Spain and Sicily, was first collected in Queensland at Macalister, Western Darling Downs, by E W Bick about March 1916. Since then it has spread to other places, but Clermont represents the northernmost locality so far recorded.

Professor H C Richards, D Sc, exhibited several beautiful specimens collected by Mr A N Falk of the zeolite Natrolite, from vughs within the weathered olivine basalt on the Main Range some 2 to 3 miles south-east of Toowoomba. He offered remarks upon the origin of the mineral, its crystalline habit, and how it may be distinguished from other zeolites.

Mr E W Bick exhibited a specimen of flowers of *Spathodea campanulata*, the tulip-tree of West Africa. The unopened flower-buds of this species contain a considerable quantity of water of glandular origin. The plant is sometimes known as the fountain-tree on account of the behaviour of the buds when punctured.

Mr J E Young exhibited matted fibrous roots of *Casuarina suberosa*, which had grown in a blanket-like mass in the crevices of consolidated sand on Stradbroke Island.

ABSTRACT OF PROCEEDINGS, 28TH JULY, 1930

The Ordinary Monthly Meeting was held in the Geology Lecture Theatre of the University on Monday, 28th July, at 8 p.m. The President, Mr J B Henderson, in the chair, and about thirty members present. Apologies were received from His Excellency the Governor, the Premier, the Minister for Agriculture, and Mr White. The minutes of the previous meeting were read and confirmed.

A paper, entitled "Two Interesting Queensland Eucalypts," by Messrs W F Blakely and C T White, was laid on the table.

Two previously undescribed eucalypts are named *Eucalyptus Curtisi* collected on sandstone hills at Plunkett, south-east of Queensland, represents a new subspecies *Leptosperma* of Benthams series *Normales*. The chief characters which necessitate the formation of a new subspecies are the terminal more or less coriaceous panicles, the toothed calyx-rim, and the narrow rugose seeds. The tree is a small one of Mallee-like growth, with smooth silvery or leaden-grey bark. The other species, *E. tenuipes*, is a stringybark or mahogany found in parts of Central or Southern Queensland, and previously named by Maiden and Blakely as a variety of the widely distributed *E. acuminoides* Schauer.

Mr A P Dodd gave an address on "The Biological Control of Prickly-pear." The first step was taken in 1912, when a Travelling Commission made a world tour, and on its return submitted a very valuable report in which it recommended the introduction of certain insects and diseases from America. Since 1919 many of these insects have been carefully studied both in America and Australia, and ten species have been established in Queensland and New South Wales. Of these, the most important are *Chelinidea tabulata*, *Tetranychus opuntiae*, *Dactylopius tomentosus*, and *Cactoblastis cactorum*, and their propagation and distribution has been the main feature of the work during the last few years. *C. cactorum* has been remarkably successful, and it is anticipated that within twelve months further distribution will be unnecessary.

Mr H K Lewcock gave an address on "The Role of Diseases in the Biological Control of Prickly-pear."

Investigations have shown that the biological control of prickly-pear in its native habitats is not due to any one pest or group of pests. Each cactus region has its own combination of cactus enemies which serve to keep the cacti under control. In every such region the components of the cactus enemy complex embrace various species of insects, various fungous and bacterial diseases and, occasionally, certain species of rodents and other small animal life. These pests react differently to changes in their environment, so that the cactus enemy complex is never static but changes considerably at different seasons of the year. In general, the insect pests are far less sensitive to external conditions than are the fungous and bacterial diseases, and are, therefore, more or less in

evidence throughout the entire year. On the other hand, certain types of diseases are definitely seasonal in their incidence and may be entirely wanting except during limited periods when conditions are favourable for their development. In the prickly-pear infested areas of Queensland, the successful introduction and establishment of such insect pests as cochineal and *Cactoblastis* has resulted, within recent years, in an amazingly rapid destruction of large tracts of dense pear. However, it has long been evident that this destruction is not due solely to the depredations of the insect pests, but that very valuable assistance is rendered by rots and other types of disease. In other words, the destruction of the pear pest in Queensland is being effected by a complex of insect, bacterial, and fungous parasites in a manner strictly analogous to the way in which the Cactaceæ are controlled by biological agencies in their native habitats. Because of the abundance of water in their tissues, succulent plants, such as prickly-pears, are particularly susceptible to attack from soft or wet rot diseases arising from either fungous or bacterial infections. Hence, it is not surprising that by far the most destructive of the diseases known to attack *Opuntias*, either in Australia or other countries, is a soft rot bacteriosis. Under favourable conditions this disease spreads rapidly throughout the entire plant, causing the complete collapse of the trunk and limbs as well as of individual cladodes. Diseases of this character are of the greatest value in destroying the pear, since insect pests, such as *Cactoblastis*, are forced to migrate from the rotted areas to healthy tissue, and thus bring about a rapid and widespread dissemination of the disease-producing organism. In fact, it is becoming increasingly evident from field observations that the extent of spread and, in consequence, the ultimate value of such a disease, is dependent on the numbers and vitality of suitable insect vectors during periods of weather favourable for the development of the disease. In addition to the soft rot bacteriosis, a number of other diseases occurring on prickly-pears in Australia were described. For convenience in presentation, these diseases were roughly grouped according to the types of injury that they commonly induce. Four such groups were distinguished. In the order of their relative importance under Australian conditions they are—(1) Fungous soft rot diseases such as that caused by *Schizophyllum commune*, (2) dry rot diseases which are probably chiefly in the nature of physiological disorders, (3) anthracnose diseases such as those caused by the fungi *Phyllosticta concava* and *Glæosporium lunatum*, and (4) the so-called "sun scald" diseases which may be caused by a variety of weakly parasitic fungi.

Mr Bennett, Dr Herbert, Prof Richards, and the President took part in the discussion which ensued, and the meeting terminated with a hearty vote of thanks to the speakers.

ABSTRACT OF PROCEEDINGS, 1ST SEPTEMBER, 1930

The Ordinary Monthly Meeting was held in the Geology Lecture Theatre of the University on Monday, 1st September, at 8 p.m. The

President, Mr J B Henderson, in the chair, and about 130 members and visitors present. The minutes of the previous meeting were read and confirmed.

Dr R Hamlyn Harris read a paper entitled "The Character of Certain Breeding Places of Mosquitoes in Australia."

Studies into the possible breeding places of mosquitoes are here continued, and it is sought by patient attention to factors involved to determine the methods underlying selection. The pH concentration seems an elusive factor, as is shown by the way in which temperature of the water and the warmth of the soils tend to determine it in a large measure. The warmer the soils the higher the pH. That the food factor plays an enormous part in the selection of breeding places is still further emphasised by careful observations in the field.

Sylvan mosquitoes undoubtedly tend to neglect waters in which a rich protozoal and bacterial fauna is missing. Mortality amongst mosquitoes in water in which a high decomposition rate is in progress is very noticeable, particularly in such instances where the death rate can be definitely traced to the toxicity of decomposition products. The ability of *C. fatigans* larvae to live for some time in water provided with a constant CO₂ blanket is incomprehensible, unless it is possible for dissolved to take the place of atmospheric oxygen.

The effects of the character in the field in Queensland are negligible, pH varies with the temperature, but sylvan mosquitoes breed freely between the narrow limits, usually in waters on the alkaline side of neutrality.

Work done on the Murrumbidgee irrigation area shows quite clearly that as the colonisation of the rice fields takes place every year, it should be possible to control mosquitoes effectively by clearing mosquitoes out of the drain ditches and other permanent breeding places at present in vogue. This would, at all events, tend to reduce to an enormous extent the incidence of mosquitoes on the Murrumbidgee irrigation area of New South Wales.

A vote of thanks, moved by Prof Goddard, supported by Dr S F McDonald and His Excellency the Governor, was carried by acclamation.

ABSTRACT OF PROCEEDINGS, 29TH SEPTEMBER, 1930

The Ordinary Monthly Meeting was held in the Geology Lecture Theatre of the University on Monday, 29th September, at 8 p.m. The President, Mr J B Henderson, in the chair, and about 40 members present. The minutes of the previous meeting were read and confirmed.

Dr L S Bagster gave a very interesting address on "The Sugar Industry" The address was accompanied by several exhibits, and illustrated by lantern slides

A vote of thanks, moved by Prof Murray, supported by Messrs Watkins and Bennett, and the President, was carried by acclamation

ABSTRACT OF PROCEEDINGS, 27TH OCTOBER 1930

The Ordinary Monthly Meeting was held in the Geology Lecture Theatre of the University on Monday, 27th October, at 8 pm The President, Mr J B Henderson, in the chair, and about 100 members and visitors present Apologies were received from the Premier, Hon A E Moore, Hon N F Macgroarty, Hon H E Sizer, and Mr Collins, M L A The minutes of the previous meeting were read and confirmed Mr W M L'Estrange was proposed by Dr E O Marks and Mr F Bennett for ordinary membership

Mr O A Jones exhibited (a) a stone axe which was found in tin wash about 15 feet deep at China Camp, near Cooktown, (b) a quartz crystal with exceptionally large grains of Cassiterite included, from the same locality

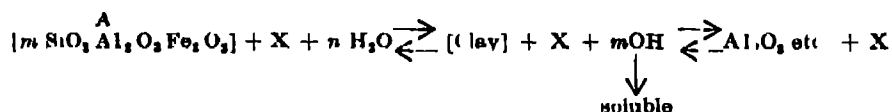
Professor H C Richards delivered a very interesting address on 'The Development of a Mining Industry by Modern Scientific Methods'

A vote of thanks moved by Mr L'Estrange, seconded by Mr Longman, and supported by Dr Robertson, Messrs Bennett, Gippa, Ball, and the President was carried by acclamation

ABSTRACT OF PROCEEDINGS, 24TH NOVEMBER, 1930

The Ordinary Monthly Meeting was held in the Geology Lecture Theatre of the University on Monday, 24th November, 1930 The President, Mr J B Henderson, in the chair, and about fifty members and visitors present The minutes of the previous meeting were read and confirmed Messrs W M Kyle, M A and W A McDougall were proposed for ordinary membership by Mr Perkins and Dr Herbert Mr W M L'Estrange was unanimously elected an ordinary member of the Society The business for the evening was a discussion on "The Distribution and Classification of Queensland Soils"

Mr H J Hines dealt briefly with the descriptions of soil in common use, and showed that none of them by itself was capable of describing fully any type of soil. However, sufficient agricultural experience had accumulated in the State to warrant the attachment of considerable importance to common descriptive terms. He then outlined the method of profile description and the generalisations proposed by the Russian and American investigators. Attention was drawn to the soil map of Australia recently published by Professor Prescott wherein types in Queensland were compared to those established in Russia. Further field investigation supplemented by laboratory determinations of "single value" soil characteristics had suggested that greater weight should be placed on the geo-chemistry of the parent material, vegetation, topography, and drainage than was apparent in Russian views. He suggested that these could be harmonised by considering the process of rock weathering in simple terms of mass action by considering the process simply as an hydrolysis. The rock-mass could be looked on as a mixture of substances, part of which (A) were relatively easily decomposed, and part (X) undecomposable, or decomposable with difficulty. This mixture reacting with water would eventually form the hydroxides of the alkalis and alkaline earths, silica, and oxides of alumina and iron. The reaction proceeded through several stages producing the common soil materials. As an equation it could be written—



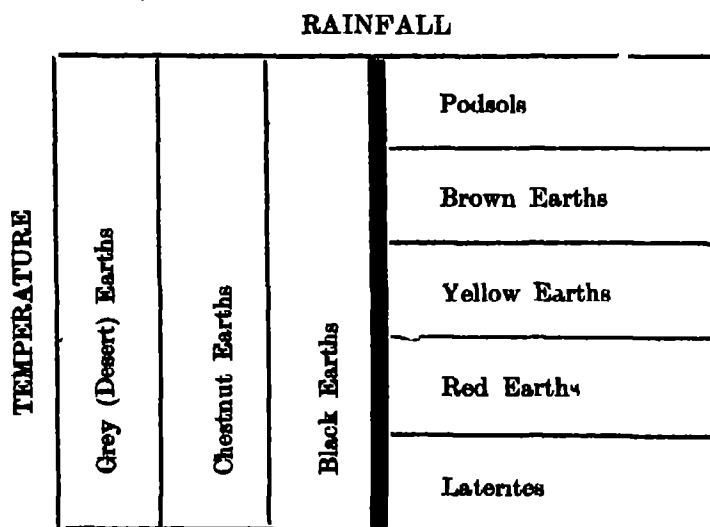
If at any one stage the reaction in the direction of the right hand side proceeded so slowly that apparent equilibrium was reached, a definite soil type could be discerned. The stage reached would depend both on the active masses of the reactants and of the products of the reaction. The active mass of A corresponded with the basicity and slight solubility of the rock, that of the water with the soil water and was thus determined by climate, topography, and texture of soil. The products of reaction of most importance were the alkali and alkaline earth hydroxides which became converted into carbonates, but were capable of yielding ions of the alkali and alkaline earth metals. Their removal was effected by drainage, and was thus dependent on precipitation, topography, vegetation, and soil texture. Hence, if rock type and topography in any area were average, climate and vegetation would dominate the formation of soil type. The further action of water was seen in the downward translocation of the clay minerals, which might

proceed slower than, as fast as, or faster than chemical decomposition according to the texture of the soil and its water relationships. This generalisation appears sufficient to explain the frequent occurrence of intrazonal soils in Queensland. As an example the black earth (chernosem) of Queensland was taken. It developed on the Cretaceous plains as a grey-brown earth, the strip of desert sandstone broke the continuity of the zone eastwards. In the Peak Downs district the true black earth developed on the more basic rocks. Here brigalow and belar thickets began to invade the grassland. The black earth then still retained its characteristic layer of calcium carbonate though becoming lighter in colour. With the advent of rain forests, however, the calcium carbonate disappeared. Highly basic rocks became deep red loams, less basic rocks brown loams with red-clay subsoils. More acidic rocks gave yellow earths and an open forest vegetation. Attention was drawn to Keen's demonstration that the maximum effective capillary rise of soil water was about 3 feet. It was pointed out that the calcium carbonate layer in the black earth occurred at a depth of about 3 feet, and hence would serve to maintain the upper soil layer in equilibrium with calcium ions. If this layer became deeper or were removed through any cause, further decomposition of the primary clay became possible. In the case of the deep red loams this was more rapid than peptisation and downward translocation. Values for oven-dry moisture and ignition loss suggest a change from the montmorillonite group of minerals to those of the kaolinite group with liberation of sesquioxides.

Dr W H Bryan dealt with the several factors which influenced the production of soil types. With reference to the climatic factor, he pointed out that the obvious parallelism of the soil zones of Russia with pronounced climatic belts was explained by the fact that temperature and rainfall both varied with the latitude, the result being a series of regular zones. In the United States of America the major soil-belts made no such regular pattern, and it had been suggested that this lack of regularity was due to the fact that, while the temperature varied from north to south, the rainfall varied from east to west. Some authors had expressed the opinion that this lack of parallelism in the two climatic factors should lead to a checkered arrangement of the principal soil types, but such a pattern was not shown by the soil map. Several attempts had been made to reconcile the distribution of soils in the U S A with the principle of climatic control by the use of composite factors based on the temperature-rainfall ratio, but these were unsatisfactory for several reasons. A study of the American soil map suggested a simple explanation of the nature of the climatic control which in spite of its simplicity seems to have been overlooked. It appeared that

where the annual rainfall exceeds a certain amount (approximately 25 inches), temperature becomes the controlling factor, and that where the precipitation falls below this value temperature is relatively unimportant and rainfall is the decisive factor. This generalisation was expressed diagrammatically as follows —

Diagram to show the relationship between some soil types and the two climatic factors



Heavy line represents 25 inches rainfall

If this arrangement does in truth represent an important principle of the relationship of climate to soil type, then it should also be applicable in areas other than U S A — e g Russia. The climatic range of Russia would occupy a diagonal strip across the diagram, and would provide the correct sequence of soil types. An arrangement somewhat similar to that of the U S A might be predicted for the soils of Eastern Australia, but the pedalferric soils would be confined to a narrower strip. Referring to Professor Prescott's soil map of Australia, Dr Bryan suggested that many of the soils of Queensland tentatively shown as Podsols were more probably the equivalents of the Yellow Earths of the U S A.

Professor J K Murray dealt with soils from the point of view of agricultural experiments.

Dr D A Herbert pointed out the importance of a study of soils with regard to plant ecology.

Professor H C Richards recommended for the consideration of the Council of the Society that a committee be formed to collect data and to prepare an account of the soils of Queensland for submission to the Third International Congress of Soil Science.

Publications have been received from the following Institutions, Societies, etc., and are hereby gratefully acknowledged.

ALGERIA—

Société de Géographie et d'Archéologie d'Oran

ARGENTINE—

Universidad Nacional de la Plata

AUSTRALIA—

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Department of Mines Melbourne

Royal Society of Victoria

Field Naturalists Club Melbourne

Council for Scientific and Industrial Research Melbourne

Department of Mines Adelaide

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Royal Geographical Society of Australasia (Queensland) Brisbane

Commonwealth Bureau of Census and Statistics Canberra

Australian Veterinary Society Sydney

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Mines Department, Hobart

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